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PRODUCTION STUDIES ON EXPERIMENTAL FARMS DAIRY HERDS

I. AGE CORRECTION OF 180-DAY MILK YIELD[1]

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ABSTRACT

Regressions of 180-day yield on age, measured in months at freshening, were fitted to the data from each of 13 herds representing three breeds. The regressions were significantly different among herds. The use of the separate herd regression for establishing age-correction factors would result in an estimated 1.3 per cent increase in efficiency over the use of the single, average within-herd regression.

In one herd, where both Holsteins and Ayrshires were maintained under similar conditions, it appeared that the Ayrshires were quicker maturing than the Holsteins. The study incidentally indicates that persistency of lactation decreases with increase in age at freshening.

Seasonal variations in age-corrected 180-day yield indicated that comparisons among contemporary cows producing within 6-month periods are likely to eliminate the misleading effects of season of freshening on yield from estimates of breeding values.

INTRODUCTION

Several reports have shown that milk yield is affected by the age of the lactating cow (5, 4, 8, 2, 6). The practical implication is that appropriate adjustments of lactation records for differences in age at the time of lactation assist in improving the effectiveness of estimating producing abilities. Also genetic interpretations of performance figures are hardly valid without adjustment for differences in age among genetic identities.

It has been shown (6, 3) that the effect of age on yield is less pronounced on total lactation yield than on yield to definite points such as 180 or 305 days following freshening. Hence, separate age-correction factors are needed on different measures of yield according to what portion of each lactation is considered. More recently (1) it has been indicated that the yield-age relationship is affected also by levels of feeding and management.

[1]Contribution from Animal Husbandry Division, Experimental Farms Service.

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From a breeding standpoint, the use of short-yield records has the advantage of making possible culling before the culls calve again and after the records on which they are being evaluated have become available. Thus, replacement heifers can replace cull mature stock more quickly. The fact that 180-day yields are not noticeably affected by gestation and are highly correlated with 305-day and longer yields (8) establishes definite advantages for the use of 180-day yield.

To accomplish the use of the first 180-day yield of each lactation as a basis for the routine estimation of breeding values in the Experimental Farm dairy herds age-correction factors were needed. Because of the general lack of information on the relationship of 180-day yield to age a study of this relationship was conducted on data collected in past years on these herds which constituted three breeds at 13 locations.

MATERIALS AND METHODS

Herd data from the major dairy herds in the Experimental Farms were analysed with punched-card equipment. The herds comprising 4 Holstein, 7 Ayrshire, and 3 Jersey herds are located in nine provinces and under different climatic conditions. All are maintained under good conditions of feeding and management although rate of feeding, time of milking, composition of feeds, and personal attention are known to be different for the period during which the records were collected. Age at freshening was measured in months and the regression of 180-day milk yield on age was studied for each herd. The total number of records studied is indicated in the form of degrees of freedom in Table 2.

TABLE 1.—REGRESSION OF 180-DAY MILK YIELD ON AGE AT FRESHENING

Farm	Av. 180-day milk yield, lb.	Av. age at freshening, mo.	Age at max. yield, mos. (xp)	Relationship between yield and age Y = expected yield x = age at freshening (mo.)
Ayrshires				
00	5987.90	56.96	94.64	$Y = 2314.44 + 102.09x - .54x^2$
41	6381.64	61.91	107.70	$Y = 3562.95 + 71.26x - .33x^2$
40	6356.16	55.51	93.37	$Y = 3391.06 + 84.16x - .45x^2$
60	5867.16	60.58	93.32	$Y = 3866.55 + 55.50x - .30x^2$
51	5881.58	60.97	89.01	$Y = 2757.74 + 90.96x - .51x^2$
50	5959.32	55.30	96.92	$Y = 2343.30 + 103.02x - .53x^2$
92	5557.52	52.91	82.50	$Y = 2008.10 + 107.06x - .65x^2$
Average	6079.65	58.73	97.41	$Y = 3121.09 + 80.89x - .42x^2$
Holsteins				
20	7519.95	58.04	99.63	$Y = 4187.70 + 75.92x - .38x^2$
90	7854.01	62.98	99.91	$Y = 4739.64 + 82.93x - .42x^2$
50	7631.45	51.22	112.65	$Y = 3175.03 + 112.84x - .50x^2$
80	7685.06	54.48	90.78	$Y = 3639.54 + 111.25x - .61x^2$
Average	7722.53	57.63	100.42	$Y = 4252.98 + 94.38x - .47x^2$
Jerseys				
11	4203.39	57.07	133.36	$Y = 2043.33 + 52.04x - .20x^2$
42	4245.98	49.83	82.63	$Y = 3117.79 + 62.15x - .38x^2$
91	5200.04	57.43	112.18	$Y = 4909.37 + 64.44x - .29x^2$
Average	4644.59	55.88	115.03	$Y = 2504.03 + 57.48x - .25x^2$

The regression used was of the form $Y = a+b_1x+b_2x^2$, where Y is the expected yield at age x and a, b_1, and b_2 were estimated by least squares analysis. The "a" value is a constant common to all records, b_1 is the linear component of the relationship yield and age, and b_2 is the curvilinear component

For the purposes of "age-correction" the mathematical maximum point was calculated for each herd by differentiating with respect to x, setting the derivative equal to zero and solving for x. Thus, maximum yield occurs at x_p. The expected yield at x_p, Y_p, was calculated by simply substituting x_p in the equation and the mature equivalent correction factors were obtained by using the formulae $\frac{Y_p}{Y_i}$ where i covers the complete age range. Consequently, the actual correction procedure was performed by $y_i\left(\frac{Y_p}{Y_i}\right)$ where y_i is the actual record. The mature equivalent method of age correction was adopted over the Breed Class Average (BCA) method because it is independent of yield. However, to illustrate the BCA method in terms of the symbols used here the formula is simply $\frac{y_i}{Y_i}$ which shows that the mature equivalent record is Y_p times the BCA index so that the results would be the same had the BCA method been used.

RESULTS

Table 1 presents the regression equation, average 180-day yield, average age at freshening, and age at maximum yield (x_p) for each herd and breed. All regressions were found to be significantly curvilinear with yield increasing to age x_p, then decreasing for older ages.

The x_p values show that maximum 180-day production does not occur until some two years after maximum 305-day yield at 6-7 years of age according to all known age-correction standards. Therefore, if these standards apply to the herds under study persistency of lactation must be rather strongly and negatively associated with age at freshening.

In Herd 50, both Holsteins and Ayrshires were maintained under similar environments. Thus, the two regressions are comparable by breed, and indicate that the Ayrshires reach maximum production sooner, and, therefore, appear to be quicker maturing than the Holsteins; but, because of the single herd environment represented, a general breed comparison is not possible.

Considerable variation exists among the b_1 values among herds within breed, and an analysis was performed to determine whether the individual herd regressions were significantly different from the breed or average-within-herd regression.

Table 2 presents, by breed, the results of this analysis which shows that for each herd the reduction in sums of squares due to fitting the individual herd regression is significantly greater for each breed than the reduction due to fitting the single breed regression. The form of analysis is given in some detail for the Ayrshire data to illustrate the method and only the values actually entering into the calculation of the "F" test are shown for the other breeds.

TABLE 2.—LEAST SQUARES ANALYSIS OF INDIVIDUAL AND AVERAGE REGRESSION

Corrected Sums of Squares

Farm	d.f.	Σy^2	$R(b_1\ b_2)$	d.f.
Ayrshire				
00	220	262,335,791	160,762,247	2
	σ^2	1,192,435		
41	592	800,505,218	324,359,352	2
	σ^2	1,352,205		
40	297	385,802,166	145,880,429	2
	σ^2	1,298,997		
60	238	428,819,058	54,679,840	2
	σ^2	1,801,761		
51	405	888,890,969	208,913,530	2
	σ^2	2,194,793		
50	318	296,218,249	227,358,339	2
	σ^2	931,504		
92	134	200,288,251	60,315,669	2
	σ^2	1,494,688		
	2218	4,445,129,108	1,182,269,406	14
	14	1,182,269,406	1,115,275,095	2
	2204	3,262,859,702	66,994,310	12
	σ^2	1,480,426	5,582,859	

$$F = \frac{5,582,859}{1,480,426} = 3.77$$

F.05 (12 and 1,000 d.f.) = 1.76
F.01 (12 and 1,000 d.f.) = 2.20

Holstein	2318	9,000,171,195	1,857,295,935	8
	8	1,857,295,935	1,759,180,581	2
	2310	7,142,875,260	98,115,354	6
	σ^2	3,092,153	16,352,559	

$$F = \frac{16,352,559}{3,092,153} = 5.28$$

F.05 (6 and 1,000 d.f.) = 2.09
F.01 (6 and 1,000 d.f.) = 2.80

Jersey	901	1,576,705,532	456,981,052	6
	6	456,981,052	435,839,579	2
	895	1,119,724,480	21,141,473	4
	σ^2	1,251,089	5,285,368	

$$F = \frac{5,285,368}{1,251,089} = 4.22$$

F.05 (4 and 400 d.f.) = 2.39
F.01 (4 and 400 d.f.) = 3.36

DISCUSSION AND CONCLUSIONS

Lush and Shrode (5) have dealt comprehensively with the age-correction problem for lactation records, and indicate that there are essentially two methods for estimating yield-age relationships. The one used in this study is based on all records, whereas an alternate approach is to use only multiple-records, that is, to include only cows that had more than one record. Of course, when selection has been practised the two methods give different results. The one used here has a tendency to bias upwards corrections for young cows. The reason for this is that when all records are included the records made at the older ages are made by selected cows. If only multiple records are used, the tendency is to bias downwards evaluations of young cows, because when multiple records alone are used the early records represent records which were high enough to cause retention for future lactations. The true relationship between age and yield lies somewhere between the regressions obtained by the two methods. Since most, if not all, available milk records are from herds where at least a degree of selection has been practised, it is not possible to obtain unbiased correction factors. Hence, those based on this study would be expected to bias upwards evaluations of records on young cows.

Another problem which exists in establishing age-corrections is that change in yield with age is affected by level of feeding and care (1). It appears that when heifers are raised in above-average conditions the increase in yield with age is less than for heifers raised poorly. Hence, if level of feeding for production is positively associated with level of feeding for heifer development, as it undoubtedly is, the relationship between yield and age is different for herds producing at different levels. Although the present data show no consistent trends for an inverse environmentally caused relationship between level of production and rate of maturity the affirmative results of a previous study, *loc cit.*, are relevant as a possible explanation of the present differences.

There are at least two explanations for the difference among herd regressions, namely, different environmental conditions and different rates of selection. Of the two, the first is considered to be of primary importance as the possibility of different rates of selection is very slight in view of the breeding and selection practices that have been in effect in all of the herds.

On the basis of the analysis presented in Table 2 the relative efficiency of using the individual herd regressions versus the average within herd regression for age correction can be calculated for each breed. This was performed by taking the ratio of the residual variances remaining after fitting the single average within herd regression and the separate herd regressions. It was found that a 1.1 to 1.5 per cent increase in accuracy would result from using separate age-correction factors for each herd as against the use of a single set of factors for all herds within a breed.

On the basis of this estimated 1.1 to 1.5 per cent increase in efficiency it can be concluded that no major savings would result from establishing separate correction factors for each herd. Similarly, if the feeding and

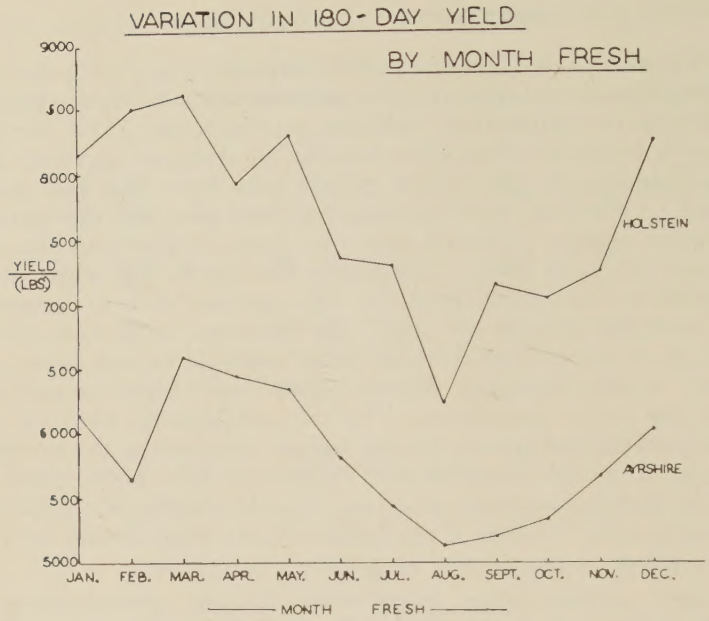

FIGURE 1.

management conditions are representative of similar conditions for herds other than those studied the average within regressions presented in Table 2 for each of the breeds would be applicable in these other herds.

Frequently the full value of age-correction of milk records is not fully realized by breeders who have available for their use age-corrected records. By only correcting the records for age with any acceptable age-correction method, very little is to be gained in estimating breeding values. This is because the major difficulty in making the estimates of breeding values lies in accounting for differences between herd and seasonal environments (1). With age-correction of records herd averages can be obtained using all records from each herd and season. By comparing age-corrected records within each herd to the age-corrected herd average the relative level of production for individuals in different herds can be used effectively to estimate breeding values substantially free from the misleading effects of herd and season environments.

For example, the age-corrected records for herd 50 in this study contained the seasonal variation represented in Figure 1. Hence, it is seen that 180-day production for freshenings in June through November is close to 1,000 lb. less than for freshenings in the other six months of the year and these six months contain the lowest production of any consecutive 6-month period in the year. This 1,000-lb. difference in actual milk production is statistically highly significant. From Table 2 the standard deviation of 180-day milk yield is 1,215 for Ayrshires and 1,758 for Holsteins. Thus, only $\left(\frac{1{,}758\ t}{1000}\right)^2$ records are needed for significance. For $t = 2$ this is 12 for Holsteins and of course less than 12 for Ayrshires. Since there are just over 300 Ayrshire and 600 Holstein records represented

in Figure 1 the seasonal difference of 1000 lb. is highly significant. Hence, with age-corrected, 180-day records, all Experimental Farms' records started in either the June through November or December through May period for each herd form the basis of evaluation for each record. The proper 6-month periods for 305-day records would not be the same but the objective in either case is to use the 6-month periods that are as different as possible in levels of performance.

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STUDIES ON THE BODY TEMPERATURE AND RESPIRATION RATE OF BUFFALO COWS UNDER NORMAL CONDITIONS

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ABSTRACT

The results of observations on the body temperature and respiration rate of 10 buffalo cows, kept in open sheds during the summer in Egypt, over a period of 24 days, are reported.

There was a wide range of variation between cows in their body reactions.

The diurnal variations in body reactions tended to coincide with diurnal variations in atmospheric conditions.

Vapour pressure was more closely correlated to physiological responses than was air temperature.

Measurements of body temperature appeared to give a better assessment of heat tolerance than did respiration rate.

INTRODUCTION

Body temperature and respiration rate in animals are influenced by climatic and other factors. It is desirable to measure these body reactions as they are primary criteria in indicating differences between animals in heat tolerance (1). Estimates of repeatability (2) of these attributes give evidence as to their relative significance in this respect. The object of the investigations reported was to determine the relative importance of air temperature and vapour pressure (7) on body temperature and respiration rate of buffalo cows. Another object of the work was to determine the repeatability of these physiological measurements.

MATERIAL AND METHODS

Ten buffalo cows from the University herd were used in this study. There were (1) four open cows in the early stages of lactation; (2) two dry cows in late stages of pregnancy; and (3) four open dry cows. The average age of these cows in lactations is given in Table 1.

The test animals were kept in open sheds and the experiment was carried out during the months of May, June and July, 1956. The summer of that year was comparatively severe in Egypt, and the animals appeared to be under more heat stress than usual.

Four observations of rectal temperature and respiration rate were made on each animal on 24 separate days. Feed was withdrawn before the tests and the cows were standing quietly. The observations were taken at 8 a.m., 10 a.m., 12 noon, and 2 p.m. Rectal temperature was measured by a clinical thermometer inserted to its full length and left in position for 3 minutes. Respiration rate was measured by counting the flank movements for two undisturbed half-minute periods and the average of the two measurements was then taken.

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TABLE 1.—NUMBER OF LACTATIONS OF EACH COW WITH (a) MEAN DAILY BODY TEMPERATURE AND RESPIRATION RATE[1] AND (b) DAILY YIELD OF THOSE IN MILK

Cows	Groups	Number of lactations	Body temperature		Respiration rate		Daily milk yield	
			Mean	Std. error	Mean	Std. error	Mean	Std. error
			°C.		½ min.		lb.	
A	1	1	38.30	0.025	10.98	0.174	14.90	0.37
B	1	5	38.29	0.025	11.10	0.165	15.60	1.10
C	1	3	38.24	0.025	10.98	0.167	12.46	0.35
D	1	2	38.25	0.021	10.74	0.156	8.08	0.28
All open lactating			38.27	0.024	10.95	0.165	12.76	0.52
G	2	2	38.35	0.025	11.36	0.190		
H	2	2	38.35	0.024	11.54	0.199		
All pregnant dry			38.35	0.025	11.45	0.194		
L	3	3	38.12	0.016	9.99	0.131		
M	3	4	38.14	0.018	9.82	0.131		
N	3	2	38.08	0.017	9.88	0.131		
O	3	4	38.14	0.017	10.19	0.130		
All open dry			38.12	0.017	9.97	0.131		

[1] Body temperatures and respiration rates were taken four times daily and the above figures are averaged from these readings.

Dry and wet bulb temperatures in the open sheds were noted at each observation using a whirling hygrometer (1).

All cows were fed on wheat straw ad libitum. The concentrate ration was given at the rate of 3 kg. daily to open dry cows and 4 kg. to pregnant dry cows. The open milking cows, however, received 3 kg. of meal, plus 1 kg. more of concentrate for every 5 lb. of milk produced.

The concentrate ration was made up of undecorticated cotton seed and rice bran at 1 : 1 ratio, and was fed in two parts, at 6.50 a.m. and 4.50 p.m.

Throughout the experiment, the cows were fed on sweet sudan grass between the hours of 10.30 a.m. and 3.30 p.m. They were watered four times daily, at 6.30 a.m., 9.30 a.m., 12.30 noon and 4 p.m. The cows in lactation were milked twice daily, at 7 a.m. and 5 p.m., and the milk yield was recorded to the nearest 0.5 lb. at each milking.

The data were classified according to cows, groups, days and readings. The analysis of variance applied was similar to the 'time' analysis given by Wilm (8) and adopted in a study by Patchell (4). Subsequent statistical methods used were as outlined by Snedecor (6).

RESULTS AND DISCUSSION

Performance of Animals

Table 1 shows the performance of the cows during the experiment. The results in Table 1 indicate that the mean body temperature and respiration rate in open milking cows were higher than the mean values obtained for the open dry cows. The values for open lactating cows were lower than those of the pregnant dry group.

The difference in body reactions of open dry cows and producing cows confirms other observations (1). The possible cause for the lower responses obtained on open dry cows is their lower metabolic rate.

TABLE 2.—MEAN, RANGE, STANDARD DEVIATION AND COEFFICIENT OF VARIATION OF THE ATMOSPHERIC AND PHYSIOLOGICAL OBSERVATIONS ON ALL COWS AT EACH OF FOUR DAILY READINGS THROUGHOUT THE COURSE OF THE EXPERIMENT

	Time of reading				
	8 a.m.	10 a.m.	12 noon	2 p.m.	Average
	Air temperature °C.				
Mean	29.36	30.27	31.27	32.95	30.96
Range	25–34	26–35	26–36	27–38	
Standard deviation	1.97	2.47	2.70	3.23	2.59
Coefficient of variation	6.71	8.16	8.64	9.80	8.36
	Vapour pressure mm. Hg.				
Mean	21.77	22.80	24.00	26.01	23.64
Range	14.1–29.6	16.0–31.7	17.6–34.6	18.7–37.9	
Standard deviation	4.62	4.59	4.68	5.56	4.86
Coefficient of variation	21.22	20.13	19.50	21.37	20.55
	Body temperature °C.				
Mean	38.24	38.16	38.21	38.29	38.23
Range	37.8–38.7	37.8–38.7	37.7–38.8	38.0–38.9	
Standard deviation	0.20	0.22	0.21	0.20	0.21
Coefficient of variation	0.52	0.57	0.55	0.52	0.54
	Respiration rate ½ minute[1]				
Mean	10.35	10.26	10.55	11.47	10.66
Range	7.5–14.5	6.5–15.5	7.5–17.5	8.0–18.5	
Standard deviation	1.38	1.49	1.61	1.53	1.50
Coefficient of variation	13.33	14.52	15.26	13.33	14.07

[1] Averages of two readings.

TABLE 3.—ANALYSIS OF VARIANCE FOR BODY TEMPERATURE AND RESPIRATION RATE

Source of variation	Body temperature			Respiration rate	
	(d/f)	(M. sq.)	(F.)	(M. sq.)	(F.)
Total	959				
B. Animals (A)	9	0.919	++	38.898	++
B. Groups (G)	2	3.892	++	167.180	++
W. Groups	7	0.070		2.246	
B. Days (D)	23	0.832	++	47.352	++
D. x A.	207	0.050	++	1.826	++
D. x G.	46	0.124	++	3.749	++
D. x W. Groups	161	0.028		1.277	
B. Readings (R)	3	0.708	++	73.327	++
R.x A.	27	0.023	O	0.911	O
R.x G.	6	0.031	O	1.242	O
R.x W. Groups	21	0.020		0.816	
R.x D.	69	0.027	++	1.379	++
D.x A.x R.	621	0.016		0.850	

O = not significant
++ = significant at 1% level

Comparison of climatic and physiological measurements (Table 2) made at different times shows that the steady rise in air temperature and vapour pressure tends to coincide with diurnal variations in body reactions. However, cows had their meal in the morning and usually consumed a large amount of wheat straw at this time while the weather was relatively cool. They also ate less straw under hot conditions. Consequently, the disturbed body reactions observed in the first readings presumably indicate effects of feed ingestion (1).

Sources of Variations in Body Temperature and Respiration Rate

Analysis of variance (Table 3) shows that there was a highly significant animal or group effect. There were also highly significant variations between animal reactions made on different days or at different times of the same day. The highly significant interactions D×A and D×G mean that animal or group responses were not the same on different days throughout the experimental period. On the other hand, the interactions R×A and R×G did not show any significant effect. This indicates that the pattern of body temperature and respiration rate behaviour from animal to animal, and from group to group, was the same for the different readings throughout the experiment. A highly significant interaction between readings and days for these body reactions is to be expected because of the variations in climatic conditions at any one reading on different days.

Correlation between Body Reactions and Climatological Observations

Simple correlation coefficients of the average daily observed physiological and climatological values were calculated for individual cows. These estimates were pooled for cows of similar groups. The results are given in Table 4. It will be seen that body temperature and respiration rate

TABLE 4.—CORRELATION COEFFICIENTS BETWEEN THE AVERAGE DAILY AIR TEMPERATURE AND VAPOUR PRESSURE AND THE AVERAGE DAILY BODY TEMPERATURE AND RESPIRATION RATE OF INDIVIDUAL COWS

Cows or groups	Correlation coefficients[1]				
	BTxRR	BTxAT	BTxVP	RRxAT	RRxVP
A	0.839	0.431	0.796	0.468	0.569
B	0.818	0.455	0.617	0.430	0.672
C	0.602	0.443	0.684	0.348	0.581
D	0.710	0.376	0.505	0.392	0.616
All open lactating	0.757	0.428	0.663	0.411	0.610
G	0.712	0.414	0.569	0.420	0.737
H	0.720	0.369	0.627	0.398	0.720
All pregnant dry	0.717	0.391	0.598	0.408	0.724
L	0.299	0.189	0.305	0.321	0.465
M	0.563	0.269	0.262	0.430	0.573
N	0.442	0.399	0.442	0.268	0.337
O	0.649	0.381	0.232	0.295	0.370
All open dry	0.498	0.311	0.312	0.331	0.443
Totals	0.663	0.375	0.528	0.379	0.577

[1] BT = Body temperature
RR = Respiration rate
AT = Air temperature
VP = Vapour pressure

TABLE 5.—SUMMARIZED COMPARISONS OF CORRELATION COEFFICIENTS FROM TABLE 4 BETWEEN THE PHYSIOLOGICAL REACTIONS IN THE DIFFERENT GROUPS OF COWS AND THE CLIMATOLOGICAL OBSERVATIONS

Groups compared	Correlation coefficients				
	BTxRR	BTxAT	BTxVP	RRxAT	RRxVP
	t-test				
Open lactating cows vs. pregnant dry cows	O	O	O	O	O
Pregnant dry cows vs. open dry cows	+	O	+	O	+
Open lactating cows vs. open dry cows	++	O	++	O	O

O = difference not significant
+, ++ = difference significant at 5% and 1% level respectively

were well correlated. However, vapour pressure appears to be more important than air temperature in determining physiological responses within the climatological pattern prevailing during the experiment. The regression obtained shows that with 1 mm. Hg. rise in vapour pressure, the rectal temperature increases by 0.012° C., and the respiration rate increases by 0.086 per half-minute.

The summarized comparison based on t-test of significance for the differences between correlation coefficients for body reactions and climatological data for all groups is given in Table 5. From this table it can be seen that there was no difference between groups in the degree of their body reactions to air temperature. The open milking and dry pregnant groups also tend to respond to the same extent to the recorded features of the environment. However, all group correlations were highly significant statistically.

Repeatability of Body Reactions

The repeatability of body temperature and respiration rate was determined by the intra-class correlation technique. The calculations were made within readings and are presented in Table 6. These results show

TABLE 6.—REPEATABILITY OF BODY TEMPERATURE READINGS AND RESPIRATION RATES OF ALL COWS

Time of reading	Repeatability estimates	
	Body temperature	Respiration rate
8 a.m.	0.232	0.181
10 a.m.	0.112	0.128
12 noon	0.120	0.078
2 p.m.	0.160	0.105
Averages	0.158	0.124

that there is a wide range of variation between estimates of body reactions at different readings. The values for body temperature tend to follow the animals' responses to the conditions at the time of observation. Similar estimates on respiration rate do not seem to follow this trend.

The repeatability estimates based on the average of four daily readings were 0.195 for body temperature and 0.172 for respiration rate. These values are, of course, higher than 0.158 and 0.124 for the two characters when single records were used (2).

It will be noted from the above results that there was little difference between the over-all repeatability estimates of these physiological responses under the conditions of the experiment. However, measurements of body temperatures, when the cows are under stress, suggest a slight superiority over the respiration rates in determining heat tolerance. The importance of body temperature in this respect had also been reported by other workers (3,5).

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A METHOD FOR THE EXTRACTION OF PIGMENTS (CHROMOGENS) FROM FECES OF CATTLE AND SHEEP[1]

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ABSTRACT

A rapid and simple method is described for the routine determination of chromogen in feces of cattle and sheep. Fresh feces, sheep 2 gm. and cattle 3.5 gm., are macerated with 5 ml. acetone, transferred quantitatively into a Bailey-Walker siphon cup, and extracted with 1000 ml. 85 per cent acetone flowing continuously over the sample at the rate of 10 to 12 ml. per minute. Absorbance of appropriate dilution (5 or 10 ml. aliquot diluted to 50 ml.) of the extract is determined at 413 mμ and the chromogen content per unit dry matter is calculated.

INTRODUCTION

Reid *et al.* (3, 4) introduced the use of fecal pigments or chromogens as internal indicators of digestibility of herbage consumed by grazing animals. In the method proposed for the extraction of these pigments, 5 to 7 gm. of feces are blended for 5 to 7 minutes with 250 to 400 ml. 85 per cent (by volume) acetone in a Waring blender equipped with an air condenser. This blending is repeated two or more times depending on the degree of pigmentation of the successive extracts.

Some of the disadvantages of this extraction method include the difficulty of ensuring tight seals at the blade assemblies and the time required for each sample. Extracts are often cloudy and ill suited to spectrophotometric measurement. Even the recommendation (1) to use an overhead drive for the blender does not answer the main criticism that the method is not sufficiently standardized and is not adapted to a large number of samples.

A continuous-extraction apparatus is used in the procedure described here and this requires only 10 minutes of the technician's attention for each extraction. The method is standardized sufficiently that it should yield reproducible results in other laboratories.

MATERIALS AND METHODS

Apparatus

The continuous-extraction apparatus is illustrated in Figure 1 and is made of the following parts:

[1] Separatory funnel, 1000 ml. capacity, calibrated to contain 900 to 950 ml. of solvent.
[2] Filter funnel, 3 in. diameter, 3 in. stem, lined with Whatman No. 42 filter paper.
[3] Wintrobe blood pipette, or soft glass tubing drawn to shape over flame, adjusted as described below to deliver 10 to 12 ml. of solvent per minute.
[4] Bailey-Walker siphon cup, lined with Whatman No. 31, 11 cm., filter paper. Use a test tube or a thimble, 22 mm. diameter, to mould the filter paper.
[5] Filter funnel, 3 in. diameter.
[6] Volumetric flask, 1000 ml.

To test the rate of flow or to start the extraction, fill the separatory funnel to the calibration mark, fully open the stopcock, slightly release the glass stopper and let the solvent rise in the filter funnel until the stem of the separatory funnel is just below the surface, then tighten stopper.

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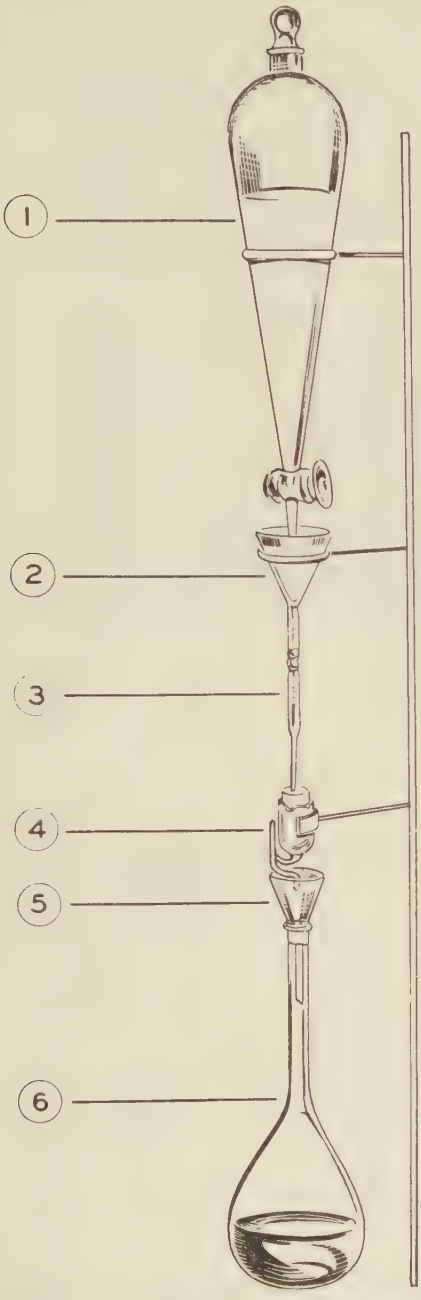

FIGURE 1. An apparatus for the extraction of chromogen from feces of cattle and sheep.

[1] Separatory funnel, 1000 ml. capacity.

[2] Filter funnel, 3 in. diameter.

[3] Wintrobe blood pipette.

[4] Bailey-Walker siphon cup.

[5] Filter funnel, 3 in. diameter.

[6] Volumetric flask, 1000 ml.

When the surface of the solvent in the filter funnel reaches the critical level, air enters the separatory funnel and acetone flows out to re-establish equilibrium. This well known phenomenon ensures constant solvent pressure at the tip of the pipette and consequently a uniform rate of flow. Obviously any air trapped within the acetone column should be eliminated. If the rate of flow is not between 10 to 12 ml. per minute, close stopcock, let drain and adjust the tip of the pipette over flame.

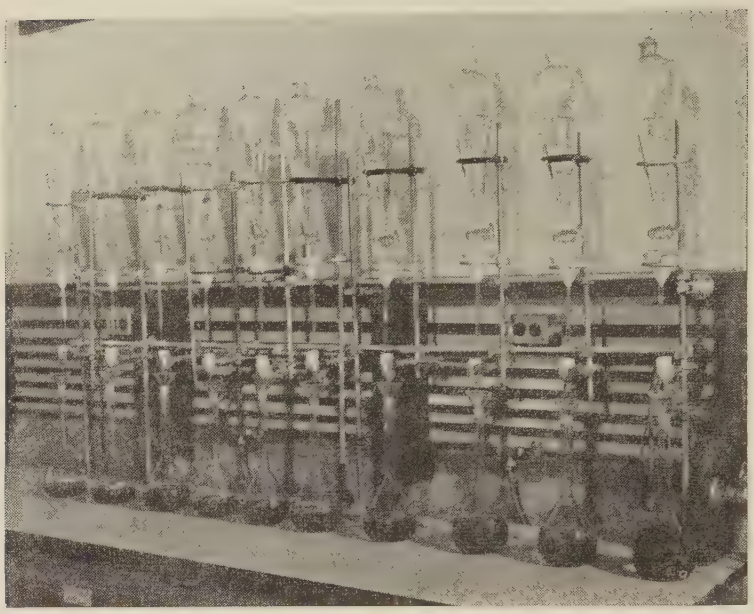

FIGURE 2. Showing a series of ten extraction units set for the routine determinations of fecal chromogen.

A series of ten extraction units set up for routine analyses are shown in Figure 2.

Procedure

Weigh accurately about 2 gm. of fresh sheep feces or 3.5 gm. of steer or cow feces into a 50 ml. beaker. Add about 5 ml. of acetone and macerate with a glass rod until a homogenous slurry is obtained. Transfer quantitatively into the extraction cup [4] using 10 to 15 ml. of solvent for rinsing, and start the extraction. When the separatory funnel is empty, add sufficient solvent through the filter funnel [2] to obtain exactly 1000 ml. of extract. Mix, take an aliquot of 5 or 10 ml., depending on concentration, and dilute to 50 ml. Measure the absorbancy at 413 mμ in a Beckman Model B spectrophotometer or any spectrophotometer with similar resolution at this wavelength. Calculate the concentration of chromogen in the fecal dry matter by the following formula:

$$\text{Concentration} = \frac{A \times F}{W \times DM} \times 100$$

A = measured absorbance
W = weight of sample in gm.
DM = dry matter content of sample in per cent.
F = dilution factor.

This eliminates the sodium chromate reference standard used by Reid *et al.* (3, 4) and is a quantitative expression of the chromogen content of 1 gm. of dry matter extracted in 1 litre of solvent.

The choice of the wavelength, 413 mμ, was based on a series of more than 50 absorption curves established with a Warren Spectracord on extracts

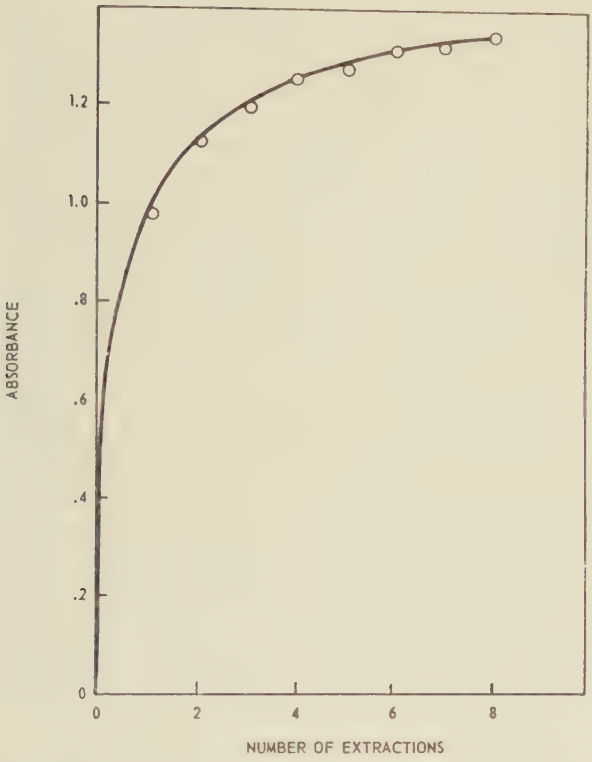

FIGURE 3. Rate of chromogen extraction from sheep feces using the blender technique. (The absorbance was calculated on the basis of 1 gm. of dry matter and 1 litre of solvent).

of sheep feces. These absorption curves showed a constant maximum absorption within 1 mμ at 413 mμ. The advantages of measuring absorbancy as near as possible the point of maximum absorption were discussed by Raymond *et al.* (2).

Continuous-Extraction Compared with Blender Method

The blender employed was the "Nelco 10" M.S.E. and the samples were blended for four periods, one of 5 minutes and three of 10 minutes each. This blending schedule was found to give the same results as six extractions of 5 minutes each using the conventional Waring blender, following Reid's method.

Preliminary investigations with the continuous-extraction technique showed that more pigments were extracted by two litres of acetone than by one litre. Therefore, the first comparisons between this and the blender techniques were made with 2-litre extracts.

Thirteen samples were extracted by the two methods and the results were submitted to an analysis of variance. Approximately 3 per cent more pigments were extracted by the continuous-extraction procedure than by the blender technique and this was statistically significant at $P = .05$. It is obvious, therefore, that all the pigments were not extracted by the blender technique.

It must be pointed out here, however, that a complete extraction of all pigments would be obtained only if the extractions were carried to infinity. This was demonstrated by extracting sheep feces by Reid's

method and measuring the absorbance of each successive extract. Reid's method was used for this demonstration because it is the most widely used method at present. The results are illustrated in Figure 3. It is seen that the rate of extraction was rapid during the first blending period but decreased progressively during the subsequent extractions. Consequently, had the analyst chosen to discontinue the extraction after the fourth blending period, the absorbance of the accumulated extract would have been only 93 per cent of that obtained after the eighth extraction. The eighth extract itself contained sufficient pigments to increase the absorbance of the previous extracts by approximately 1 per cent. Although complete extraction of all pigments is not necessary for practical use, it is obvious that, under such conditions, the extraction procedure must be strictly standardized.

The volume of solvent required for 2-litre extracts was found somewhat cumbersome. For that reason a comparison was made between 2-litre and 1-litre extracts on 55 samples of sheep feces. The absorbancy of the first and second litre was measured separately and was calculated on the basis of 1 gm. of dry matter in 1 litre of extract. The summation of the absorbancies of both extracts was made equal to 100 per cent extraction. It was found that 97.1 per cent of the pigments were extracted by the first litre of acetone. Thus, the 3 per cent greater extraction obtained by the continuous-extraction procedure in the above test was due entirely to the pigments extracted by the second litre of solvent. It appeared, therefore, that an extract of 1 litre would be sufficient for practical purposes and give results comparable to the blender technique.

The absorbancies of each litre of extract obtained in this experiment were grouped according to pigment concentration in order to show the effect, if any, of reducing the volume of extracts to 1 litre when the chromogen content of the samples varied from less than 1.000 to more than 2.000.

TABLE 1.—A COMPARISON BETWEEN BLENDER AND CONTINUOUS EXTRACTION METHODS.

Sample number	Blender	Continuous-extraction (1 l. extract)
	Absorbance (1 gm. of dry matter in 1 litre of solvent)	
1	2.069	2.106
2	1.462	1.435
3	1.531	1.532
4	1.270	1.339
5	3.247	3.365
6	1.282	1.296
7	1.074	1.087
8	0.866	0.837
9	1.076	1.074
10	1.298	1.300
11	1.866	1.839
12	1.767	1.707
13	1.825	1.713
14	0.492	0.495
15	1.199	1.190
16	2.089	2.090
17	2.440	2.420
18	0.588	0.595
19	0.778	0.770
20	3.205	3.170

The number of samples extracted at low, intermediate and high concentration were 19, 16 and 20 respectively.

At low concentration, i.e. less than 1.000, the pigments extracted by the second litre of solvent increased the optical density of the extract by 2.61 ± 0.32 per cent as compared to 2.71 ± 0.24 and 3.31 ± 0.22 per cent at intermediate and higher concentrations respectively. This apparent increase at higher concentration was not significant statistically by "Student's" t test. An important interpretation of this observation was that for all practical purposes an equal proportion of the pigments present in the sample was extracted by the first litre of solvent irrespective of the concentration.

A further comparison between the continuous-extraction technique (using only 1 litre of solvent) and the blender procedure was made with twenty samples of sheep feces. The results were summarized in Table I. If the average concentration obtained by the blender technique was made 100.0, the concentration obtained by the continuous-extraction procedure was 99.8. It is obvious that such a small difference between these two methods could be of no practical importance even if it were real. The procedure using 1 litre of extract, therefore, was adopted.

Rate of Flow of Solvent

A set of ten extraction units was assembled for routine chromogen determination as illustrated in Figure 2. The Wintrobe blood pipettes were roughly adjusted to deliver the solvent at various rates from less than 9 to more than 20 ml. per minute. A series of five to twelve extractions were made on six different samples. Because of an unequal number of observations at the various speeds, the results were expressed as per cent of the mean concentration at the lowest speed (9.5 or less).

The results which are given in Table 2 show that the rate at which the acetone flows over the sample being extracted is not important provided that it is less than 15 ml. per minute. No statistical difference was found by "Student's" t test between the various speeds up to 15 ml. per minute. Consequently speeds of 10 to 12 ml. per minute were adopted.

Size of Sample

The reliability of this continuous-extraction procedure with samples of various sizes was tested with thirteen samples of sheep feces. Different amounts of dry matter were taken for each of two extractions carried out on each sample. An average of 0.7662 gm. and 0.9860 gm. of dry matter was taken for the first and second series of determinations, respectively. An analysis of variance showed no significant difference between the average optical density of the extracts from each series. It is apparent, therefore, that variations as great as 30 per cent between the amounts of fecal

TABLE 2.—EFFECT OF RATE OF FLOW OF SOLVENT ON EXTRACTION OF CHROMOGENS
(Rate of flow in ml. per minute)

	9.5 or less	9.5 to 10.5	10.5 to 12.5	12.5 to 15.0	15.0 to 20.0	20.0 or more
No. of observations	9	11	11	11	12	4
Chromogen extraction per cent	100.0	100.6	97.7	97.7	95.8	92.2
Standard error of mean	±.68	±.87	±.98	±.65	±.96	±1.57

material taken for extraction do not affect the accuracy of this method. Variations greater than 30 per cent were not tested.

Reproducibility

The reproducibility of this new method was estimated by calculation of fiducial limits (5). It was found that 95 per cent of the determinations in duplicate were reproduced within ± 5.1 per cent and ± 3.4 per cent when sheep and cow feces were used, respectively.

DISCUSSION

Several hundred samples have been analysed by the continuous-extraction procedure in this laboratory. It was found that the simplicity and rapidity of this technique are two important advantages over the blender method. The extraction apparatus requires no special equipment and has eliminated any mechanical device subject to wear. The handling of the equipment, samples and solvent is reduced to a minimum which eliminates some sources of error. It is readily adapted to routine determination if several units are assembled as shown in Figure 2. When the routine is well established, each sample does not require more than about 10 minutes of attention. A setting of more than four or five units should be placed in a well ventilated laboratory because the acetone vapours might be sufficient to be objectionable.

It is important to note that the entire extraction is made with fresh acetone and that the extracting power of this solvent remains uniform throughout the extraction. For that reason, the percentage of pigments extracted from each sample is practically the same irrespective of the pigment concentration in the samples. This is an advantage over any technique where the extraction is made by soaking or shaking the fecal material in the totality or portion of the solvent used.

The reproducibility of this extraction procedure does not appear to be as high as most analytical methods by chemical means but it was found to be appreciably higher than that of nitrogen determinations made on the same fecal samples. It is noted that in calculating the fiducial limits the variation due to the extraction technique was confounded with the variations due to the fecal material analysed. It is felt that a great proportion of this error was due to the variations within the fecal samples. This was strongly indicated by the higher reproducibility obtained when cow feces were analysed as compared to sheep feces. Due to the rapidity of this new extraction procedure, sampling error can easily be reduced by replicating the determination several times.

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EXPERIMENTAL ERRORS IN EGG PRODUCTION EXPERIMENTS[1]

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ABSTRACT

Data from 14 egg production experiments, which had replicated pens and individual trapnest records, were analysed to obtain estimates of experimental error from which to determine pen effects. The experiments were all nutrition experiments and were conducted at four experimental stations.

Analyses were carried out on both a hen-housed and survivor basis. For all experiments the sampling error (*individuals*) underestimated the experimental error (*individuals* + *pens*) by about 20 per cent on a hen-housed basis. On a survivor basis there was no evidence of pen effects, that is, the sampling error did not underestimate the experimental error.

The coefficient of variation for all experiments was 40 per cent on a hen-housed basis and 25 per cent on a survivor basis.

The relative efficiency of two experimental designs, randomized block and completely randomized, was calculated for 11 of the experiments (on a hen-housed basis only). With the exception of 2 experiments, there was an increased efficiency of up to 500 per cent in utilizing a randomized block design. The data further indicate that the increase in efficiency obtained with a randomized block design is much more marked when the blocks represent different houses than when the blocks consist of different locations within a house.

INTRODUCTION

The choice of the proper error term for testing treatment differences has been discussed by many statisticians. As stated by Homeyer and Pauls (4) in their study of chick nutrition experiments, "a valid estimate of the experimental error in estimating the true differences in gains among rations must contain a properly weighted component for all factors or groups of factors, other than rations, that influence these differences. Equally important, the estimate of experimental error should not contain components of variation for factors that do not influence the estimated differences in gains".

In egg production experiments where birds are kept in pens and the treatment is applied to the pen as a unit, two sources of variation contribute to the experimental error. The first of these can be ascribed to the birds themselves, while the second source arises from effects other than treatments which may vary from pen to pen, often called "pen effects". These pen effects may result from various causes, which can differ from experiment to experiment.

In designing egg production experiments, a knowledge of the variation to be expected is necessary to ensure adequate replication. Many estimates of the variation obtained in egg production experiments are based on the variability associated with birds within pens. However, such estimates take no account of the possibility of pen effects, and therefore cannot be assumed to be adequate in the planning stages of an experiment.

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TABLE 1.—PERFORMANCE OF HENS IN 14 EGG PRODUCTION EXPERIMENTS. DURATION OF TESTS, EGG PRODUCTION, MORTALITY, NON-LAYERS, FLOOR EGGS

Experiment No.	N47	N48	N49	N50	N51	N52	N53	N54	K51	K54	S54	B52	B53	B54
Duration of test (days)	140	112	280	280	280	280	280	336	308	279	333	274	280	336
Hen-housed production (no.)	71	49	156	139	135	157	176	193	198	186	140	145	147	203
Hen-housed production %	51	44	56	50	48	56	63	57	64	67	42	53	53	60
Survivor production %	57	45	60	54	54	59	72	66	67	74	46	57	56	62
Mortality %	6	2	11	13	17	11	24	18	2	8	17	11	9	4
Non-layers %	8	3	1	2	2	1	1	3	3	7	1	2	2	1
Floor eggs %	13	-	5	3	4	—	2	2	2	2	—	4	3	2

TABLE 2.— DESIGN OF 14 EGG PRODUCTION EXPERIMENTS

Experiment No.	N47	N48	N49	N50	N51	N52	N53	N54	K51	K54	S54	B52	B53	B54
Design[1]	R.B.	R.B.	R.B.	R.B.	R.B.	R.B.	R.B.	R.B.	R.B.	R.B.	R.B.	C.R.	R.B.	C.R.
Blocks														
Houses	2	2	2	2	2	2	2	2	3	3	3	(1)	(1)	(1)
Blocks w/i h.	2	2	2	5	2	2	2	1	1	2	1	—	—	—
Replicates	4	4	4	10	4	4	4	2	3	6	3	3	3	3
Treatments	4	4	4	4	4	5	5	10	2	2	3	3	3	3
Birds/pen	20	20	20	20	20	45	45	56	50	25	50 : 60	63	65 : 80	60
Experimental birds														
Hatches	1	1	1	1	1	1	1	1	6	5	4	6	(2)	1
Breeds	1	1	1	1	1	1	2	2	1	1	1	1	(2)	1
Prev. treat.	—	—	—	—	—	—	—	—	—	—	—	—	—	2
Allotment to pens[2]	Ran.	Ran.	Ran.	Ran.	Ran.	Ran.	Rst.	Rst.	Ran.	Rst.	Ran.	Rst.	Ran.	Rst.
Total birds per experiment	320	320	320	800	320	900	900	1120	300	300	480	567	630	540

1. *R.B.*—Randomized block design
   C.R.—Completely random design

2. *Ran.*—Random
   Rst.—Restricted

Dudley and Read (2) stress the importance of having adequate pen replication in egg laying experiments. However, in five experiments which they analysed they found appreciable pen effects in only one test. Hale (3) concluded from a study of fourteen egg production experiments that egg production records are seldom affected to any serious extent by differences between pens that are treated similarly. Further information on this subject is desirable. Although it is not possible to predict in advance whether pen effects will be important in a given experiment, if adequate information on past experiments is available, one can, to a certain degree, safeguard the experiment through adequate replication.

DESCRIPTION OF DATA

The data for this study were obtained from fourteen experiments conducted at four Farms of the Experimental Farms Service, Canada Department of Agriculture. One farm provided data from eight experiments, one farm from three, one farm from two, and one from a single experiment.

The duration of the tests, total production, and percentage production, as well as the mortality, percentage of non-layers and percentage floor eggs for the various experiments, are presented in Table 1. All the birds used in these experiments were pullets, hatched in the spring months. They were trapnested on either a 5 or 7 day-week basis, but all results have been reported as 7-day production by converting the 5-day figures. The duration of the tests varied from 112 days (N48) to 336 days (N54, B54) although the majority of the experiments were approximately 280 days or 9 months in duration.

The details of the experiments with respect to design are given in Table 2. In all experiments the treatments were replicated on a pen basis. A randomized block design (R.B.D.) was used in most of the experiments although a completely randomized design (C.R.D.) was used for two of the tests (B52 and B54). Blocks in most cases consisted of separate houses with further blocking arrangements within the houses. However, in one experiment (B53) blocks consisted of breeds and hatches. The number of replicates in these experiments varied from two (N54) to ten (N50). The number of birds per pen varied from 20 to 80 but was uniform within each test except for two experiments (S54, B53), in which two different pen sizes were proportionally allotted among treatments and blocks. The number of birds in the experiments varied from 300 (K51, K54) to 1120 (N54).

A number of these experiments utilized birds from more than one hatch or from more than one breed. In general, where more than one hatch of birds was used, the hatches were spaced a week apart. In assigning the birds to the pens in these experiments either of two procedures was employed. In experiments K51 and S54 no attention was paid to the different hatches, and all birds available were assigned to the pens at random. In experiments N53, N54, 54K and B52 the assignment to the pens was restricted on a within-hatch or breed basis, that is, at random within a given hatch or breed. In one experiment (B54) restriction was made on the basis of a previous range treatment.

The treatments imposed in these experiments are not described in this paper. They have been or will be reported by the various investigators who conducted the tests. It is not felt that the treatments employed would have any serious effect on the conclusions drawn from this study.

STATISTICAL ANALYSIS

Twelve of the experiments were analysed as randomized block experiments while the remaining two were analysed as completely randomized experiments. The analyses of variance are shown in Table 3. "Sampling error" is used in Table 3 and throughout this paper to indicate the remainder or within-pen mean square. "Experimental error" refers to the mean square associated with pens receiving the same treatment.

All experiments were analysed both on the basis of the number of hens housed and on a survivor basis. In the latter case, only the birds which survived the test were considered. In these analyses the term "survivor" was further restricted to include only those birds which lived and which laid eggs; birds which lived but had no recorded egg production were not used. Floor eggs were not included in any of the analyses.

The analyses used on a hen-housed basis were those appropriate to experiments with proportionate sub-class numbers, while all analyses on a survivor basis were completed by the method of fitting constants.

In the case of hen-housed egg production for those experiments where the allotment of birds to the pens was restricted on the basis of hatch, breed or previous range treatments, the analysis took the form appropriate to a split plot design in which the "n" values for the sub-classes were proportionate. For the analyses on the basis of survivors, however, the mean square was estimated after removing the effect of the hatch or breed on a within-pen basis. This remainder mean square has been referred to as "sampling error 2".

Table 3.—The analyses of variance

Completely Randomized Design

Source of variation	*d.f.*
Treatments	t-1
Experimental error (pens within treatments)	t(p-1)
Sampling error (individuals within pens)	pt(k-1)

Randomized Block Design

Source of variation	*d.f.*
Blocks	b-1
Treatments	t-1
Experimental error	(b-1)(t-1)
Sampling error	bt(k-1)

t—number of treatments
b—number of blocks
p—number of pens
k—number of individuals per pen

The coefficient of variation was obtained for each experiment. This coefficient in each case was based on the experimental error mean square. To obtain estimates of the coefficients of variation which could be used to compare all experiments, a constant pen size of 25 birds was assumed for each experiment, and the coefficient re-calculated for each experiment by using the value of 25 for k in the expected mean square for experimental error.

Source of variation	*Expected mean square*
Experimental error	$\delta^2_s + k\delta^2_E$
Sampling error	δ^2_s

Where k = the number of birds per pen.

This assumes that the estimate of δ^2_E is not influenced by the pen size.

For those experiments (S54, B53) in which two pen sizes were used, the estimate of δ^2_E was obtained as described by Smith (5). With unequal and disproportionate sub-class numbers the value of k was calculated by the method suggested by Snedecor (6).

The efficiency of an experiment conducted as a randomized block design relative to the same experiment had it been a completely randomized design was calculated according to the method given by Cochran and Cox (1) for comparing these designs.

RESULTS AND DISCUSSION

The mean squares for experimental error and sampling error as well as the degrees of freedom on which these errors are based are presented in Table 4. The experimental error on both a hen-housed basis and on a survivor basis varied over a wide range. This may be attributed, at least in part, to the fact that the duration of the experiments differed, but since examination of the data reveals no consistent relationship between the duration of the test and the size of the experimental error, it must be concluded that other factors are also responsible.

It is of interest to note that, in those experiments in which there was some restriction placed on the allotment of the birds to the pens, and in which two sampling errors were computed, sampling error 2 in every case except one (B54 for hen-housed production) was smaller than sampling error 1. This indicated that the allotment of the birds on a restricted basis increased the sensitivity of the experiment. Considering the basis for the restriction, namely hatches and breeds, this would be expected. However, with one exception (survivor production, N54), both sampling errors are larger than the experimental error. This could result from competition effects between groups in the same pen.

In Table 5 the experimental error is shown as a percentage of the sampling error. In most cases the experimental error and sampling error were of the same order of magnitude although in three cases (N47 and S54 on a hen-housed basis and S54 on a survivor basis) the experimental error was more than twice as large as the sampling error. In two experiments (N53 and B53), the experimental error was less than half as large as the sampling error. Using a weighted average, the experimental error for all experiments is 120 per cent of the sampling error on a hen-housed basis and 99 per cent on a survivor basis. It could be concluded from these

TABLE 4.—THE MEAN SQUARES FOR EXPERIMENTAL AND SAMPLING ERRORS ON A HEN-HOUSED AND SURVIVOR BASIS

Experiment No.	N47	N48	N49	N50	N51	N52	N53	N54	K51	K54	S54	B52	B53	B54
Hen-housed production														
Experimental error	2086	484	3409	3438	2549	4339	1428	4980	3936	4258	6401	3215	2929	2528
Sampling error (1)	979	580	2279	2795	2700	2640	3720	5682	2921	5905	2695	2527	2811	3577
(2)							3687	5606		5820		n.a.		3610
Survivor production														
Experimental error	598	327	1613	2098	668	1540	633	2906	2005	2417	3689	1667	602	1668
Sampling error (1)	460	630	1271	1746	1320	1823	1209	3763	1934	3014	1713	1376	1715	3103
(2)							1147	2822		2791		n.a.		2971
Degrees of freedom														
Experimental error	9	9	9	27	9	12	12	9	2	5	4	6	4	6
Sampling error H.H.	304	304	304	760	304	880	880	1100	294	288	471	558	621	531
Surv.	266	283	264	652	248	776	666	900	280	242	388	495	565	509

n.a.— not available

TABLE 5.—EXPERIMENTAL ERROR EXPRESSED AS A PERCENTAGE OF SAMPLING ERROR

(Sampling error = 100%)

Experiment No.	Hen-housed basis %	Survivor basis %
N47	213	130
N48	83	52
N49	150	127
N50	123	120
N51	94	51
N52	164	84
N53	39	55
N54	89	103
K51	135	104
K54	73	86
S54	238	215
B52	127	121
B53	104	35
B54	71	56

results that the sampling error underestimates the experimental error when the analysis is carried out on a hen-housed basis but not on a survivor basis. Therefore pen effects only appear when the data are analysed on a hen-housed basis. As hen-housed production reflects mortality, it is conceivable that the mortality is not independent of the pen.

Floor eggs were not included in the analyses and this probably causes a bias in the estimates of the errors. Inclusion of the floor eggs would correct the bias in the experimental error, but would not correct the sampling error because there is no basis on which to assign the floor eggs to the individual birds. Consequently, inclusion of the floor eggs would tend to distort the relationship between the experimental and sampling errors, which in this study is of prime concern. For this reason it was decided to exclude floor eggs from the analyses.

Although the experimental error was 99 per cent of the sampling error when averaged for all experiments, and therefore does not supply any reason to indicate pen effects when the analyses are made on a survivor basis, the distribution of these percentages suggests that other effects might be operative. For example, five of the percentages (N48, N51, N53, B53, B54) are 60 per cent or less. This could result from the presence of competition effects within pens, and consequently the presence of pen effects could not be isolated if this situation were operating.

The coefficients of variation (on a pen basis) are presented in Table 6 for each experiment as it was conducted. For comparative purposes each coefficient was also calculated on a 25 bird per pen basis. This is based on the assumption that pen effects are not related to the size of the pen. On a hen-housed basis the coefficient varied from 5.5 (B54) to 13.7 (N47) with an average for all experiments of 7.8 for a 25 bird pen. The range on a survivor basis is from 2.3 (N51) to 6.9 (S54) with an average for all experi-

TABLE 6.—COEFFICIENTS OF VARIATION

Calculated for the experiments as conducted and on a theoretical basis of 25 birds per pen

Experiment No.	Birds/pen	Hen-housed		Survivor	
		In expt.	25 birds/pen	In expt.	25 birds/pen
N47	20	14.4	13.7	7.4	6.5
N48	20	10.0	8.8	8.1	6.0
N49	20	8.4	7.8	5.7	5.0
N50	20	9.4	8.6	7.3	6.3
N51	20	8.4	7.4	4.3	2.3
N52	45	6.3	7.6	3.8	4.9
N53	45	3.2	5.6	2.2	2.8
N54	56	4.9	7.6	3.6	4.8
K51	50	4.5	5.9	3.2	4.3
K54	25	7.0	7.0	5.2	4.7
S54	50 : 60	7.8	9.5	6.0	6.9
B52	63	4.9	7.3	3.9	5.0
B53	65 : 80	4.4	7.3	2.0	4.5
B54	60	3.2	5.5	3.1	4.7

ments of 4.9. On an individual bird basis the coefficients of variation would be 39 per cent and 25 per cent for hen-housed and survivors respectively. Although there may be some question whether these coefficients based as they are on experiments of different duration should be averaged, the average does however serve a purpose, and is probably as good an estimate as one can obtain from these data. Titus (7) concludes from his own data, as well as from various reports in the literature, that when planning an experiment a coefficient of variation of 20 per cent and preferably 25 per cent should be assumed. These coefficients as suggested by Titus (7) are based on survivor egg production. Under certain situations, if the investigator does not wish to assume that treatments should be evaluated on survivors only, a coefficient of at least 40 per cent based on hen-housed would be in order.

These coefficients of variation encountered in egg production studies are extremely large. As pointed out by Titus (7), the number of birds required to show a significant difference is high. For example, according to Cochran and Cox (1), 13 replications (13 pens of 25 birds) are required, when the true treatment difference is 5 per cent to show significance at the 5 per cent level with a probability of 80 per cent. This assumes a coefficient of variation of 5 per cent on a survivor basis. Thirty-three replications (33 pens of 25 birds) assuming a coefficient of variation of 8 per cent are required on a hen-housed basis. Very few egg production experiments ever meet these levels. The design, the number and arrangement of treatments would also be factors entering into estimates of number of pens required for a given experiment.

The efficiency of a randomized block design relative to a completely randomized design is given in Table 7 for each of the experiments which were conducted as randomized block experiments These relative efficiencies were computed on the basis of hen-housed production only. In

TABLE. 7.—RELATIVE EFFICIENCIES OF RANDOMIZED BLOCK AND COMPLETELY RANDOM DESIGNS

Mean square obtained when analysed as completely random design expressed as % of M.S. obtained when analysed as randomized block design

Experiment No.	%	Experiment No.	%
N47	108	N54	159
N48	94	K51	340
N49	121	K54	138
N50	81	S54	131
N51	128	B52	—
N52	115	B53	811
N53	592	B54	—

two of the experiments (N48 and N50) the efficiency of the experiment was not increased through the use of a block design. However, in all other experiments there was a definite increase in efficiency ranging from 108 per cent (N47) to 592 per cent (N53), where blocks consisted of some physical arrangement of the facilities. In B53 the block arrangement was based on breeds and hatches. Further analyses of the data from those experiments based on block arrangement of physical facilities suggest that most of the increased efficiency came from the use of houses rather than from blocking arrangements within houses.

This is similar to the results of the experiment reported by Titus (7) who found significant differences between houses in his uniformity trial. Egg production is influenced greatly by environment, and these environmental effects would be expected to be greater between units such as houses than between pens within a house. It is difficult to generalize in this problem for all circumstances but the results of these studies would indicate that blocking arrangements of the experimental facilities are worthwhile, especially if the facilities consist of units such as houses.

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THE ENDOGENOUS URINARY AND METABOLIC FECAL NITROGEN EXCRETIONS OF NEWBORN DAIRY CALVES[1]

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ABSTRACT

Daily observations were made on the fecal and urinary nitrogen excretions of four calves fed nitrogen-free diets during the second and fifth weeks after birth. The endogenous urinary nitrogen excretion was equivalent to 65.3 mg. per kg. of body weight (W) per day or 186 mg. per kg. $W^{0.72}$. The metabolic fecal nitrogen excretion averaged 44.0 mg. per kg. of body weight per day or 0.334 per cent of the dry matter intake.

INTRODUCTION

An estimate of the biological value of a protein (11) or the calculation of protein requirements by factorial methods (1) requires accurate information on the endogenous urinary and metabolic fecal nitrogen excretions. Information on the protein metabolism of preweanling calves is meagre and the data obtained in studies with older animals (5) are not sufficiently adequate to warrant extrapolation.

Blaxter and Wood (2), employing semi-purified, nitrogen-free diets, found that the endogenous urinary nitrogen excretion of three Ayrshire calves was 81.9 mg. per kg. of body weight per day. The metabolic fecal nitrogen excretion was 0.427 gm. per 100 gm. of dry matter ingested. Lofgreen and Kleiber (9) studied radioactive phosphorus which had been incorporated into the casein of calf diets and reported values of 0.27 gm. of metabolic fecal nitrogen per 100 gm. of dry matter intake. Harris and Loosli (7), working with 137-day-old calves, found that the endogenous urinary nitrogen excretion was 41 mg. per kg. of body weight per day and the metabolic fecal nitrogen excretion was 0.372 gm. per 100 gm. of dry matter intake.

In view of the divergence of these reports, it seemed advisable to investigate further the endogenous urinary and fecal nitrogen excretions of young calves before a study was made of the protein requirements for growth.

EXPERIMENTAL PROCEDURE

Two Holstein and two Ayrshire male calves weighing from 33.9 to 48.5 kg. were removed from their dams at 2 days of age. They were kept in wire-floored digestion pens equipped for the separate collection of urine and feces. Room temperature was thermostatically controlled at 70 to 75° F. The purified diets (Table 1) were prepared by a method similar to that of Wiese *et al.* (13) with modifications described previously (6). A nitrogen-free diet was prepared by replacing the casein with an equal weight (air-dry basis) of glucose. The caloric values of the casein, glucose and lard were determined in a Parr bomb calorimeter. Fresh diets were prepared three times weekly, stored at 34° F., and warmed to 100° F.

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TABLE 1.—COMPOSITION OF THE PURIFIED DIETS

Ingredient	Casein diet	Nitrogen-free diet
	(gm. per kg. of fluid diet)	
Crude casein[1]	40.0	—
Cerelose[2]	50.0	90.0
Lard[3]	28.0	28.0
Lecithin	2.0	2.0
Minerals[4]	9.9	9.9
Vitamin A palmitate	5,000 I.U.	5,000 I.U.
Vitamin D_3	500 I.U.	500 I.U.
Alpha-tocopherol acetate (mg.)	10	10
B-vitamins[4]		

[1] The crude casein contained 8.31 per cent moisture and had a fuel value of 5.86 Calories per gm. of dry matter.
[2] The cerelose contained 9.00 per cent moisture and had a fuel value of 3.76 Calories per gm. of dry matter.
[3] The lard was homogenized with the lecithin before adding to the diet. The fuel value of the mixture, lard + lecethin, was 9.48 Calories per gm.
[4] Same mixture as used previously (6).

before feeding. The calves were weighed weekly to the nearest 100 gm. and were fed at the rate of 12 per cent of body weight per day. The diet was given twice daily by pail and fresh water was provided *ad libitum* at all times.

Each calf received the nitrogen-free diet during the second and fifth weeks after birth. The casein diet was fed during the first and fourth weeks (preliminary periods) and third week (recovery period). Seven-day total feces and urine collections were made during the preliminary and recovery periods while 1-day sub-collections were made during the nitrogen-free periods.

The feces were collected four times daily and stored at 34° F. with toluene and dilute HCl as preservatives. Upon completion of a collection period the feces were macerated in a Waring blendor and weighed. Aliquots were withdrawn and analysed for total lipids by the Saxon method (8). Dry matter, nitrogen and ash were determined by standard procedures and carbohydrate was obtained by difference.

The urine was collected daily in bottles containing a few drops of toluene and sufficient HCl to maintain acidity. The urine was weighed each day and a 5 per cent aliquot was withdrawn and stored at 34° F. Aliquots from each of the 7-day preliminary and recovery periods were composited. The composited samples and those from the 24-hour sub-collections on the nitrogen-free diets were analysed for nitrogen by the kjeldahl procedure.

RESULTS AND DISCUSSION

The 7-day collection period on the nitrogen-free diet was completed in five cases. The collections were terminated after 5 days in one case and after 4 days in two cases because of feed refusals, diarrhoea, tremors and heavy breathing. Similar observations of severe diarrhoea and shivering when calves were fed nitrogen-free diets were reported by Blaxter and Wood (2). Diarrhoea was not in evidence during the eight preliminary periods but was responsible for the loss of some collections in one recovery period.

Digestibility and Body Weight Changes

Data on digestibility of the diets are presented in Table 2. In order to illustrate the changes in digestibility resulting from the removal of nitrogen from the diet, average digestibility coefficients are given for each successive 24-hour period that the calves received the nitrogen-free diet. An analysis of variance indicated that the apparent digestibility of fat, ash and carbohydrate was significantly lower ($P < 0.01$, 0.05, 0.05 respectively) during the nitrogen-free periods than during the preliminary periods. A similar fall in digestibility was noted in other experiments when calves were fed nitrogen-free (2) or low protein diets (3,4), but some calves in the present experiment completed 7-day periods without any evidence of diarrhoea and yet excreted a greater volume of feces which resulted in a lower diet digestibility. The digestible energy intake, however, was still above the required level for maintenance of young calves (4) or the theoretical level at which body protein is deaminated for energy.

The data in Table 3 show that all calves gained weight during the preliminary periods (average of 0.36 kg. per calf per day) and were in satisfactory condition to encounter the nitrogen-free periods which followed. All but one calf lost weight during the nitrogen-free periods with an average weight loss of 0.17 kg. per calf per day. The weight losses may be explained by the fact that more body protein is deaminated than synthesized by animals on energy adequate nitrogen-free diets. This results in a loss of body weight unless it is countered by the storage of fat, water or other material.

TABLE 2.—AVERAGE DIGESTIBILITY OF THE DIETS AND NITROGEN EXCRETION

	7-day Preliminary	Days on nitrogen-free diet							7-day Recovery
		1	2	3	4	5	6	7	
No. of observations	8	8	8	8	8	6	5	5	3
Dry matter dig. (%)	94.4	88.9	86.6	88.8	86.1	86.0	81.4	85.9	91.6
Fat dig. (%)	87.9	68.4	62.9	68.5	60.0	61.9	43.3	59.0	78.7
CHO dig. (%)	99.9	99.9	99.0	99.0	98.5	98.4	98.4	98.1	98.9
Ash retention (%)	90.5	84.6	84.6	86.8	84.6	82.2	75.6	80.8	83.0
Dig. Cal./kg./day	67.7	54.1	52.4	53.9	51.4	50.1	44.8	52.8	62.8
Fecal N/100 gm. dry matter intake (gm.)	0.33	0.38	0.38	0.31	0.32	0.31	0.37	0.26	0.32
Urinary N/kg./day (mg.)	281	170	108	84	72	66	64	66	260
Fecal N/kg./day (mg.)	42.8	50.6	48.6	42.6	41.4	39.3	37.3	34.2	42.1

TABLE 3.—AVERAGE DAILY BODY WEIGHT CHANGES

Calf No.	Initial weight (kg.)	Weeks on collection				
		1 Preliminary	2 N-free	3 Recovery	4 Preliminary	5 N-free
		(average daily gains in kilograms)*				
1	39.7	0.40	−0.15	0.41	0.24	0.11
2	48.5	0.44	−0.25	−0.01	0.45	−0.43
3	40.8	0.26	−0.15	0.47	0.50	−0.24
4	33.9	0.13	−0.15	0.28	0.47	−0.13

* Average daily weight changes during the nitrogen-free weeks are given for the time the calves remained on the nitrogen-free diets. All periods were of 7 days' duration except for calf 2, where both nitrogen-free periods were 5 days, and in the case of calf 3, where the second nitrogen-free period was 4 days.

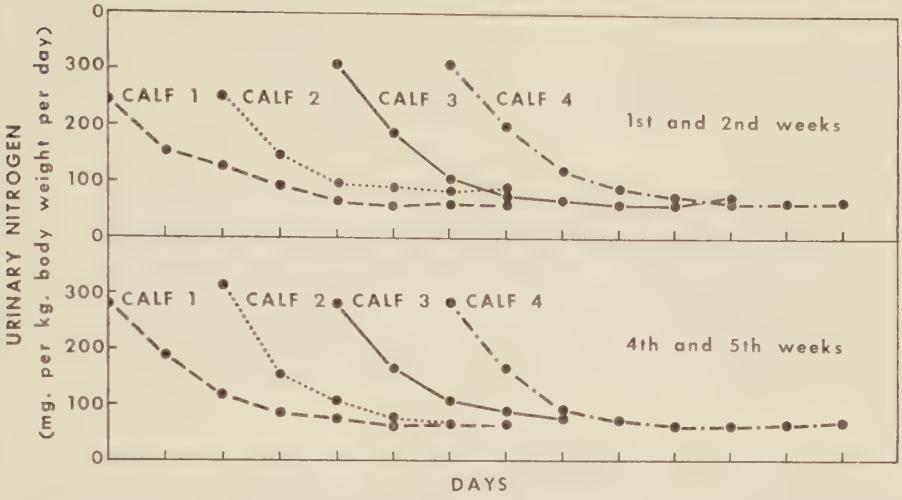

FIGURE 1. Urinary nitrogen excretion of calves fed nitrogen-free diets. Initial value = average daily excretion during a 7-day preliminary period during which the calves were fed a diet containing protein.

Metabolic Fecal Nitrogen

Removal of the casein from the diet did not result in any significant change in the fecal nitrogen excretion. This would indicate that the true digestibility of the casein was 100 per cent and that the nitrogen excreted during both the preliminary and nitrogen-free periods may be considered to be of metabolic origin. The fecal nitrogen excreted during the nitrogen-free periods averaged 44.0 mg. per kg. of body weight per day or 0.334 per cent of the dry matter intake. This is considerably higher than the total fecal nitrogen excreted by calves fed diets containing whole milk and skim milk powder protein (4). Blaxter and Wood (2) also observed that calves excreted more fecal nitrogen when they received a nitrogen-free diet than when they were given a diet containing skim milk protein.

It has been recognized for some time that metabolic fecal nitrogen is more closely associated with dry matter intake than with body weight (12). Since increases in the cellulose content of the diet result in marked increases in the excretion of metabolic fecal nitrogen and fecal dry matter (10,11) it has been suggested (2, 11) that fecal dry matter would be a more reliable indicator of metabolic fecal nitrogen than feed intake. However, in the present studies, when the diet of the calves was changed from casein to the nitrogen-free diet, large quantities of undigested fat were excreted without any change in the excretion of fecal nitrogen. Experiments with rats (12) have also shown that metabolic fecal nitrogen is unaffected by the proportion of fat in fecal dry matter. This indicates that variations in digestibility of fat would result in erroneous estimates of metabolic fecal nitrogen if the calculations were based on fecal dry matter output.

Endogenous Nitrogen

The daily urinary nitrogen excretion of each calf is shown in Figure 1. Average values of these data are given in Table 3. It may be observed that minimum excretions were reached within 4 or 5 days after the casein

was removed from the diet with only small variations between calves or replicates. The nitrogen excreted from the fifth to seventh day was considered to be entirely of endogenous origin. The average excretion for fifteen 24-hour collections during this period was 65.3 mg. kg. of body weight per day. This is lower than a reported value of 81.9 mg. per kg. of body weight per day obtained after 2 days on a nitrogen-free diet (2).

Brody (5) calculated from experiments reported in the literature that the endogenous nitrogen excretion of mature animals of different species was 146 mg. per kg. of body weight $^{0.72}$ per day but suggested that the nitrogen metabolism of young growing animals was probably higher. In agreement with this, the young calves in the present study excreted 186 mg. of endogenous nitrogen per kg. of body weight $^{0.72}$ per day.

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THE PROTEIN AND ENERGY REQUIREMENTS OF YOUNG DAIRY CALVES[1]

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ABSTRACT

The protein and energy requirements of pre-weanling dairy calves were studied through the use of growth and balance trial techniques. Various levels of protein and energy were fed in both purified and semi-purified diets. The nitrogen retention of calves fed diets adequate in protein was 3.22 gm. per 100 gm. of gain in body weight. Energy requirement for maintenance was 44.7 digestible Calories per kg. of body weight per day and 268 digestible Calories were required per 100 gm. of gain in weight. These factors, along with previously determined values for endogenous nitrogen, were used to calculate the practical digestible energy and apparent digestible protein requirements of dairy calves.

INTRODUCTION

Whole milk or milk products constitute an expensive item in the diet of dairy calves. In order to successfully replace these products with cheaper substitutes, adequate information is needed on the calf's protein and energy requirements. Appreciable information is available on the requirements of the weanling calf (1, 5, 10, 11) but very little is known regarding the requirements between birth and two months of age.

The National Research Council (1), aware of this lack of information, recommended daily allowances of digestible protein equivalent to amounts generally consumed when whole milk is fed. Although the protein content of milk may be adequate for optimum growth, lower levels might be sufficient and more economical.

Protein requirements of farm animals often are reported as percentage of dry matter intake. In view of variations in energy content of calf diets, it would be more accurate to express protein requirement as a percentage of energy intake. Mitchell and Beadles (14) observed in experiments with rats that the protein: energy ratio necessary for maximum growth was the same over a wide range of energy intake. Studies were not made under maintenance conditions but, since the growth stimulated by each increment in energy intake was not accompanied by a requirement for a higher protein: energy ratio, it may be interpreted that the same protein: energy ratio was required for growth as for maintenance. Should this apply to rats, it does not apply to the young calf which requires a lower protein: energy ratio for maintenance than for growth (7). Therefore, it would appear that studies on protein requirements of calves must be planned to yield information on the requirements for both maintenance and growth. The present work included such studies.

EXPERIMENTAL PROCEDURE

Trial 1

Eight Holstein and eight Ayrshire male calves were fed colostrum for 3 days after birth and then allotted according to breed and body weight

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into four equal groups. Management of the animals, collection and preservation of urine and feces, and analytical procedures were the same as those described in a previous report (9).

The purified diets shown in Table 1 were similar to the nitrogen-free diet used previously (9) with the exception that crude casein partially replaced cerelose at four different levels. Feed intake was adjusted to body weight at the beginning of each of four successive 14-day periods. The calves were fed the fluid diets at the rate of 8 per cent of body weight during the first period and 10 per cent thereafter. Feces and urine collections

TABLE 1.—COMPOSITION OF THE PURIFIED DIETS FED IN TRIAL 1

Ingredient	Diet 1	Diet 2	Diet 3	Diet 4
	(gm. per kg. of fluid diet)[1]			
Crude casein	20.0	30.0	40.0	50.0
Cerelose	70.0	60.0	50.0	40.0
Lard[2]	28.0	28.0	28.0	28.0
Lecithin	2.0	2.0	2.0	2.0
Minerals[3]	9.9	9.9	9.9	9.9
Vitamins[4]				
Antibiotic[5]				
Protein (% of dry matter)[6]	14.7	22.1	29.5	36.9
Protein (% of energy)	16.7	24.3	31.5	38.3

[1] Water was added to constitute 87% of the diet as fed.
[2] The lard was homogenized with the lecithin before being added to the diet.
[3] Minerals in gm. per kg. of diet: $Ca(OH)_2$, 1.0; KOH, 0.959; NaOH, 0.928; $CaCl_2$, 1.565; $CaCO_3$, 0.140; Conc. HCl, 0.101; $FeSO_4.7H_2O$, 0.050; $CuSO_4.5H_2O$, 0.004; $CoCl_2.6H_2O$, 0.0014; $MnSO_4.4H_2O$, 0.0034; $ZnSO_4.7H_2O$, 0.0031; KI, 0.0003; MgO, 0.298; KH_2PO_4, 2.873; citric acid, 1.998.
[4] Vitamins in mg. per kg. of diet: thiamine, 0.65; riboflavin, 0.65; niacin, 2.5; choline chloride, 260.0; folic acid, 0.052; pyridoxine, 0.65; para-aminobenzoic acid, 2.60; calcium pantothenate, 1.30; B_{12}, 0.025; alpha-tocopherol, 5.0; vitamin A palmitate, 5000 I.U.; vitamin D_3, 500 I.U.
[5] Procaine penicillin G, 2 mg. per kg. of fluid diet.
[6] The casein and cerelose contained 10.57 and 9.00 per cent moisture, respectively.

TABLE 2.—COMPOSITION OF THE DIETS FED IN TRIAL 2

Ingredient (%)	Diet 5	Diet 6	Diet 7	Diet 8
Whole milk	66.67	66.67	66.67	66.67
Skim milk powder	—	2.30	4.61	6.91
Water	26.42	26.42	26.42	26.42
Minerals[1]	1.01	0.68	0.33	—
Cerelose	5.90	3.93	1.97	—
Vitamins[2]				
Antibiotic[3]				
Protein (% of dry matter)[4]	13.6	18.7	24.0	29.3
Protein (% of energy)[4]	17.1	22.8	28.7	33.9

[1] Mineral mixture in gm. per kg.: Calcium lactate, 525; $Ca(OH)_2$, 36; K_2HPO_4, 287; NaCl, 120; $MgSO_4.7H_2O$, 24.7; $FeSO_4.7H_2O$, 6.4; $MnSO_4.H_2O$, 0.32; $CuSO_4.5H_2O$, 0.32; $ZnCl_2$, 0.16; $CoSO_4.7H_2O$, 0.08.
[2] Vitamins in mg. per kg. of fluid diet: riboflavin, 0.40; thiamine HCl, 0.40; pyridoxine HCl, 0.40; niacin, 1.35; Ca-pantothenate, 0.68; inositol, 3.4; para-aminobenzoic acid, 0.34; folic acid, 0.013; biotin, 0.0068; B_{12}, 0.0088; alpha-tocopherol, 3.3; vitamin K, 0.3; choline chloride, 70.0; vitamin A palmitate, 700 I.U. vitamin D_3, 200 I.U.
[3] Procaine penicillin G, 2 mg. per kg. of fluid diet.
[4] These figures are averages of all batches of each diet prepared during the course of the experiment, but the actual nutrients for each calf varied with the composition of the whole milk and skim milk powder fed during each period.

were made during the last 7 days of each period. The caloric values of the diets were calculated using experimentally determined (9) fuel values of 5.86, 9.48, and 3.76 Calories per gram for protein, fat (lard) and carbohydrate, respectively. The same factors were used to calculate the calorific content of feces.

Trial 2

Protein requirements determined with purified diets may differ from those found with practical rations. For this reason, whole milk and dried skim milk powder were used as main constituents of the diet in this trial.

Two Holstein and two Ayrshire male calves weighing from 42.5 to 57.5 kg. were used. All animals were fed each of the diets shown in Table 2 for a period of 7 days in a 4 × 4 latin square design. The first 2 days of each period served as preliminary to a 5-day collection period during which urine and feces were collected quantitatively. The "milks" were fed at the rate of 12 per cent of body weight per day with adjustments to body weight changes at the beginning of each week.

The whole milk was obtained from the Ayrshire and Holstein herd of the Central Experimental Farm. Representative samples of this pooled milk and of the skim milk powder were analysed by standard procedures (3) for total solids, nitrogen, fat, ash, and lactose.

Caloric values of 5.86, 9.11, 3.95, and 3.76 per gram of dry matter were used for protein, fat (butterfat), lactose, and cerelose, respectively. The caloric value of the lactose in the calcium lactate was included in the calculations of the energy content of the diets. The fuel values applied to fecal protein, fat, and carbohydrate were 5.86, 9.11, and 3.95, respectively.

EXPERIMENTAL RESULTS

Trial 1

The apparent digestibility coefficients for protein, fat, and gross energy are averaged for each diet during each collection period in Table 3. The data for Ayrshire and Holstein calves were combined because there were no statistically significant breed differences. There was a significant ($P < 0.01$) increase in the apparent digestibility of the protein in progressing from diet

Table 3.—Apparent digestibility coefficients of protein, fat, and gross energy in trial 1

	Period	Diet 1	Diet 2	Diet 3	Diet 4
Protein	1	68.8	79.5	86.6	93.8
	2	81.0	87.9	91.9	92.8
	3	82.4	88.5	92.3	93.1
	4	83.7	89.6	94.4	94.2
Fat	1	65.6	71.2	81.0	90.1
	2	77.2	77.1	80.4	81.0
	3	76.7	79.5	86.1	81.5
	4	78.3	81.0	88.9	87.0
Gross energy	1	79.5	82.6	87.9	93.6
	2	86.7	87.2	89.1	89.4
	3	86.7	88.3	89.8	89.6
	4	87.6	89.2	93.5	92.4

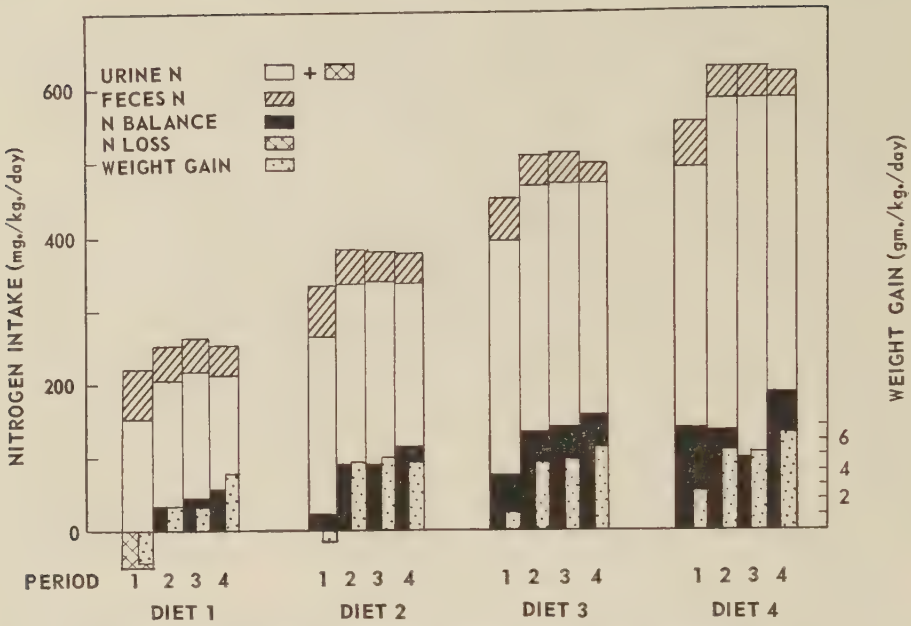

FIGURE 1. Weight gains and nitrogen balance data of the calves in Trial 1.

1 to diet 4. A lower apparent digestibility of protein on low protein diets was expected because with such diets metabolic fecal nitrogen represents a larger percentage of the nitrogen intake.

The fecal nitrogen excretion averaged 0.46, 0.45, 0.38, and 0.36 per cent of the dry matter intake by calves fed diets 1, 2, 3, and 4, respectively. There was no significant difference between these values as indicated by an analysis of variance. Since fecal nitrogen excretion of calves fed similar but nitrogen-free diets was 0.33 per cent in previous work (9), it would appear that the true digestibility of the casein in all diets was near 100 per cent.

The digestibility of the fat of diets 1 and 2 was significantly lower ($P<0.01$) than that of diets 3 and 4. It may be noted that calves fed nitrogen-free or low protein diets are usually subject to diarrhoea and consequently exhibit lower diet digestibility (6, 9). In this trial, however, the feces of the calves on the low protein diets were fluid only occasionally. Therefore it would appear that aside from the tendency to induce diarrhoea a reduction in the level of protein may have a depressing effect on the digestibility of fat.

The results obtained on nitrogen balance and body weight gains are illustrated in Figure 1. All values were expressed as mg. per kg. of body weight per day based on the mean weight for the period. It is seen that more nitrogen was retained as the level of protein increased to that of diet 3. This increase from diet to diet was significant ($P<0.01$) as shown by an analysis of variance. Increasing the protein content to that of diet 4 had no statistically significant influence on nitrogen retention. Thus it appears that optimum nitrogen retention was reached when the protein was

equivalent to 31.5 per cent of the energy intake. It is possible, however, that restricted energy intake and lower energy digestibility of diets 1 and 2 (Table 3) had a limiting effect on nitrogen retention.

The calves fed diet 2 grew faster ($P<0.01$) than those fed diet 1 but there was no statistically significant difference between the growth rates of the calves fed diets 2, 3, and 4. It appears that optimum growth was reached when protein constituted 24.3 per cent of the energy intake.

The nitrogen retained per 100 gm. of gain averaged 1.59, 2.53, 3.05, and 2.79 gm. for diets 1 to 4, respectively. Thus the nitrogen retention for each increment of body weight was lowest when the protein content of the diet was at the minimum. In similar experiments, Blaxter and Wood (8) observed a nitrogen retention of 1.28 gm. per 100 gm. of weight gain when low protein diets were fed. This indicates that level of dietary protein may influence the composition of the gain of calves.

It is commonly accepted that a true measure of the biological value of a given protein can only be obtained on a low-protein energy-adequate diet (13). Since the calves in this trial were restricted in their energy intake, the biological values for casein fed in these diets were calculated by Mitchell's method (13) for the two levels of energy intake. The values of 65.3 mg. for endogenous nitrogen and 0.33 per cent of the dry matter intake for metabolic fecal nitrogen [reported previously (9)] were used in the calculations. The calculated biological values are summarized in Table 4. Highest values were obtained with diet 1 where casein was fed at the lowest level. An exception to this was the low biological value of 32.2 in period 1, diet 1, which resulted from a low level of gross energy intake combined with a reduced energy digestibility. The highest biological value 64.9, is not the maximum obtainable for casein since other workers (8) using a lower level of casein in energy-adequate diets obtained an average biological value of 78.8. The wide variations in the biological value of casein in this

TABLE 4.—AVERAGE BIOLOGICAL VALUES CALCULATED FOR CASEIN IN TRIAL 1

Period	Diet 1	Diet 2	Diet 3	Diet 4
1	32.2	37.2	39.2	34.6
2	59.0	51.8	46.0	33.0
3	59.0	50.5	47.2	31.7
4	64.9	56.7	49.6	37.7

TABLE 5.—APPARENT DIGESTIBILITY COEFFICIENTS FOR THE DIETS FED IN TRIAL 2

Diet	DM	Fat	Protein	Ash	CHO	Gross energy
5	97.9	97.4	94.5	91.0	99.5	98.0
6	98.1	97.9	95.9	93.9	99.3	98.1
7	98.4	98.3	97.2	94.5	99.5	98.5
8	98.4	97.9	97.7	95.0	99.5	98.4

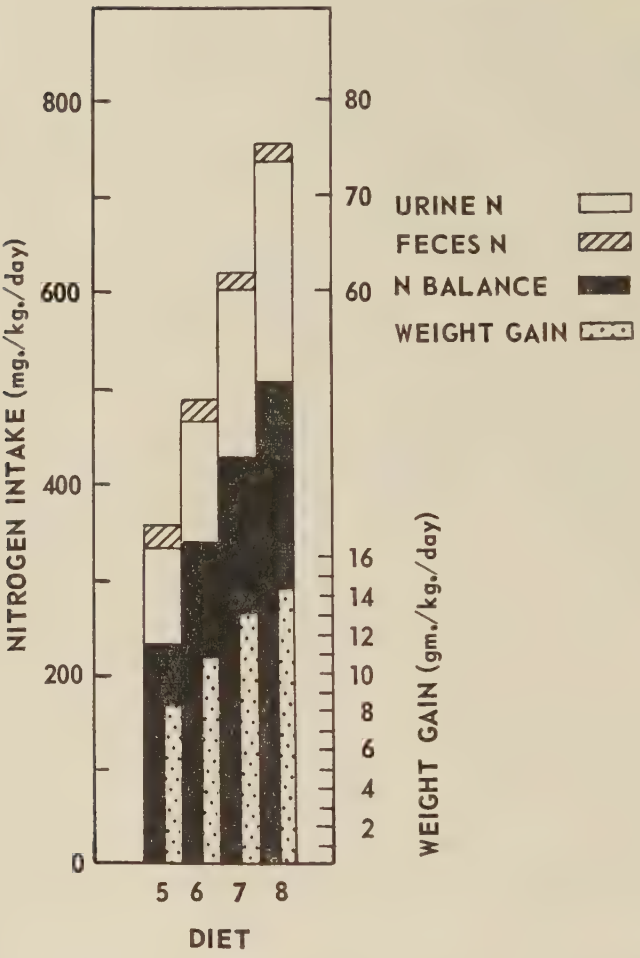

FIGURE 2. Weight gains and nitrogen balance data of the calves in Trial 2.

experiment resemble those in other studies with calves (7) in which the biological value of skim milk protein varied from 40.0 to 87.9, depending upon the intake levels of protein and energy.

Trial 2

The coefficients of digestibility for all diets fed in this trial are summarized in Table 5. It may be seen that the apparent digestibility coefficients of the energy of all diets were considerably higher than that of any of the diets fed in Trial 1 (Table 3). This was mostly due to the higher digestibility of butterfat as compared to that of the lard which was used as a source of fat in Trial 1.

Body weight gains and the results of the nitrogen balance trials are shown in Table 6. Averages of these data, expressed as gm. or mg. per kg. of body weight per day, are shown in Figure 2. There was a statistically significant increase in weight gain and nitrogen retention ($P < 0.01$) as the

protein content of the diet increased. Figure 2 indicates that the rate of gain began to level off at the highest level of protein supplementation but there was not a sufficient number of observations to show this trend to be statistically significant. As in Trial 1, the ratio of nitrogen balance to weight gain (Figure 2) indicates that more nitrogen was retained per unit of body gain with the higher levels of protein. The calves retained an average of 2.57, 3.08, 3.27, and 3.48 gm. of nitrogen per 100 gm. of gain on diets 5, 6, 7, and 8, respectively. These figures are slightly higher than those obtained for diets 1 to 4 in Trial 1, possibly due to the higher total digestible energy intake and higher biological value of the protein of diets 5 to 8.

Nitrogen excreted in feces was equivalent to 0.12 per cent of the dry matter intake. This was less than the nitrogen excretion of calves fed nitrogen-free diets in previous experiments (9). Therefore all the fecal nitrogen was assumed to be of metabolic origin when calculating the biological value of the protein. The biological values of the whole milk and skim milk proteins in Table 6 are considerably higher than those shown for casein in Table 4. Skim milk protein is known to have a higher biological value for calves than isolated casein (8). This, combined with the higher energy intake, may account for the higher biological values observed in Trial 2.

TABLE 6.—BODY WEIGHT AND NITROGEN BALANCE FOR THE CALVES IN TRIAL 2

Calf No.	Period No.	Av. body wt. (kg.)[1]	Body wt. gain/day (gm.)	Dig. Cal. intake	NI	UN	FN	NB	B.V.[2]
					(gm. per day)				
				Diet 5					
3	1	52.28	551	3934	18.08	4.89	1.15	12.04	91.8
1	2	52.67	536	3940	18.05	4.94	1.20	11.91	91.7
2	3	67.81	453	5218	23.79	7.31	1.41	15.07	87.9
4	4	57.95	486	4582	22.11	6.89	1.52	13.70	85.9
				Diet 6					
2	1	57.55	503	4565	28.00	7.51	1.48	19.01	86.6
3	2	56.81	744	4162	26.81	7.27	.73	18.81	86.7
4	3	54.03	633	4483	27 00	6.98	1.80	18.22	87.2
1	4	62.59	647	4954	30.51	8.12	.71	21.68	86.8
				Diet 7					
1	1	48.81	567	3810	30.13	8.15	.89	21.15	83.5
4	2	49.49	664	3766	30.24	8.94	.97	20.33	81.1
3	3	62.82	971	5347	39.66	9.74	1.08	28.84	85.8
2	4	72.57	907	5558	44.57	11.91	1.09	31.57	83.9
				Diet 8					
4	1	44.84	664	3730	34.16	10.90	1.27	21.99	76.7
2	2	62.77	989	4933	45.72	14.73	.98	30.01	76.7
1	3	57.44	826	4548	42.04	13.44	.74	27.86	76.9
3	4	69.40	908	5956	55.17	14.66	1.19	39.32	81.6

[1] Average body weights recorded at the beginning and end of period.
[2] B.V. calculated using a value of 65.3 mg. per kg. of body weight for endogenous nitrogen and assuming 100% true digestibility of protein.

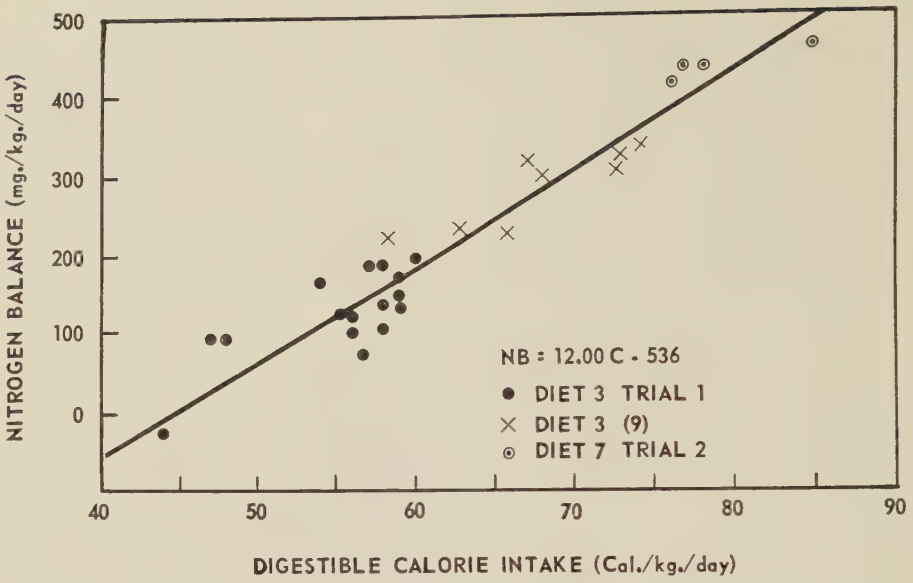

FIGURE 3. Relationship of nitrogen balance (NB) to digestible Cal. intake (C) for diets 3 and 7 in Trials 1 and 2, respectively, and for calves fed diet 3 for 7-day periods in accompanying experiments (9).

DISCUSSION

As mentioned above, the energy and protein requirements of calves must be determined for both maintenance and growth. The energy requirement for maintenance may be estimated from the results obtained with diet 3, Trial 1, and diet 7, Trial 2. These diets were adequate in protein and were fed at various levels of intake in Trials 1 and 2 and in a similar concurrent experiment reported previously (9). Figure 3 shows the linear regression of nitrogen balance (NB) on digestible Cal. (C). At the intercept with the x axis, i.e. when NB = O, C = 44.7. This means that for maintenance, 44.7 digestible Cal. are required for each kg. of calf weight per day. This is slightly lower than the maintenance requirement of 52.4 Cal. reported by Blaxter and Wood (6).

The energy requirement for growth can be derived from the regression of body weight gains in gm. per kg. of body weight per day (W) on digestible energy intake using the same body weight basis. The regression obtained in these experiments is shown in Figure 4. When W = O, that is at body weight maintenance, C = 44.8, which is obviously the same as above. The slope of the regression curve is a quantitative expression of the body weight increment resulting from the intake of one digestible Cal. Therefore 1 digestible cal. stimulated 0.373 gm. of gain and 100 gm. of gain would require 268 digestible Cal. This is in good agreement with the work of Soxhlet cited by Armsby (2) from which it can be computed that the caloric content of 100 gm. gain would be 258 and 280 Cal. for 4- and 8-weeks-old calves, respectively.

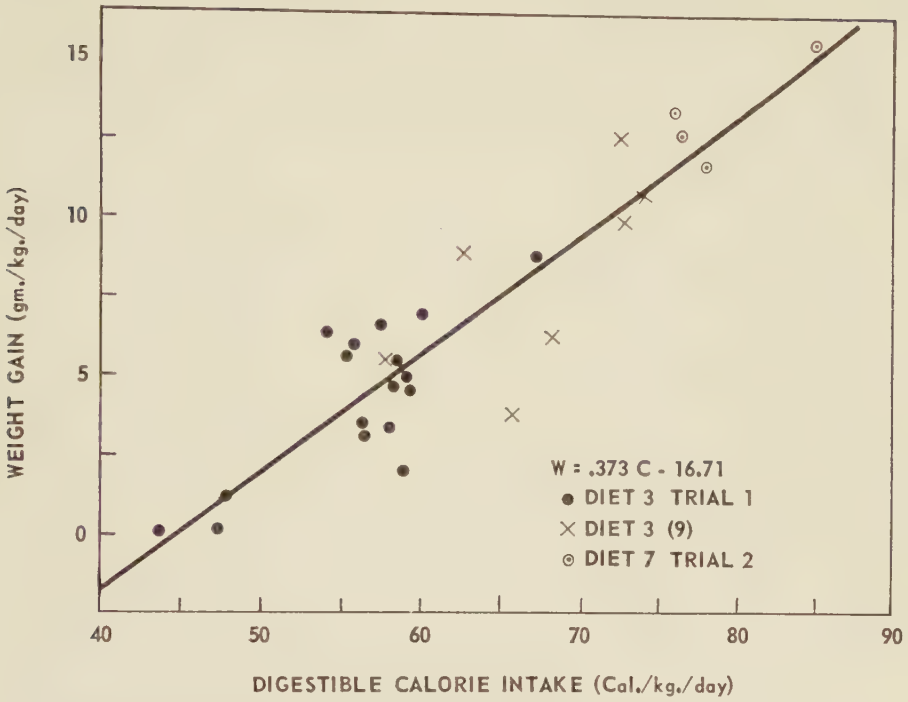

FIGURE 4. Relationship of weight gain (W) to digestible Cal. intake (C) for diets 3 and 7 in Trials 1 and 2, respectively, and for calves fed diet 3 for 7-day periods in accompanying experiments (9).

An interpretation similar to that above can be made from the regression curve given in Figure 3. The slope of this regression curve indicates that 12.00 mg. of nitrogen was retained for each digestible Cal. consumed. Since one unit of digestible energy produced an increment in body weight of 0.373 gm. it can be calculated that 3.22 gm. of nitrogen was retained per 100 gm. of gain. This value agrees with data on protein content of body weight gains of normal calves (2, 15), and on nitrogen retention per unit of gain (4). In one study (2), for example, the nitrogen content of the entire carcass of calves was 1.67 per cent for 185-day embryos, 2.84 per cent at birth, 3.18 per cent at 3 months, and 3.05 per cent at 5.5 months. It is apparent that to increase total body protein, the nitrogen retention per unit of body weight increase must be higher than the average nitrogen concentration of the whole body at any of the ages mentioned here.

The protein and energy requirements for maintenance and growth as determined in these experiments may be used to predict the dietary requirements under practical conditions if losses occurring during various metabolic processes are taken into account. When the biological value of a protein is 100,

$$ADN = EN + NB \qquad (A)$$

where ADN = apparent digestible protein,
EN = endogenous nitrogen,
NB = nitrogen balance or nitrogen retained.

For proteins of high biological value, such as those generally fed to young calves, the error involved in using this formula is negligible. Therefore, using the factors 65.3 mg. per kg. per day for EN and 32.2 mg. per gm. of body gain for NB, the apparent digestible protein requirements may then be predicted by applying the equation

$$ADN = 65.3 + 32.2\ G \qquad (B)$$

where ADN = mg. of apparent digestible protein per kg. of body weight per day and G = growth rate in gm. per kg. per day.

Similarly, the energy requirements can be predicted as follows:

$$E = 44.7 + 2.68\ G \qquad (C)$$

where E = digestible energy in Cal. per kg. of body weight per day and G = growth rate in gm. per kg. per day.

The requirements for digestible energy and apparent digestible protein were calculated in Table 7 for calves at various growth rates with protein having a theoretical biological value of 100. It may be observed that the protein requirements given as a percentage of the digestible energy intake are higher with faster growth rates. The growth rates of normal heifer calves according to the Beltsville standards (12) increase from 0.6 per cent of body weight during the first 10 days after birth to 1.0 per cent from 50 to 60 days. The energy requirements of these calves, according to Table 7, would increase during these periods from 61 to 71 Cal. per kg. of body weight per day. The requirement for apparent digestible protein of a biological value of 100 would increase from 15.6 to 19.8 per cent of the digestible energy intake, respectively. For proteins of biological values less than 100 the protein requirements would increase proportionately. For example, if the biological value of the protein being fed was known to be 85, the protein requirements would be increased 15 per cent.

TABLE 7.—CALCULATED REQUIREMENTS OF CALVES FOR ENERGY AND APPARENT DIGESTIBLE PROTEIN WITH A BIOLOGICAL VALUE OF 100

	Gain in per cent of body weight per day							
	0.0	0.2	0.4	0.6	0.8	1.0	1.2	1.4
Total Cal./kg./day[1]	44.7	50.1	55.4	60.8	66.1	71.5	76.9	82.2
Total ADN required /mg./kg./day[2]	65.3	129.7	194.1	258.5	322.9	387.3	451.7	516.1
Apparent digestible protein required as per cent of digestible energy[3]	5.3	9.5	12.8	15.6	17.9	19.8	21.5	23.0

[1] Based on 44.7 Cal./kg./day for maintenance and 2.68 for growth as in equation (C).
[2] Based on 65.3 mg. EN/kg./day for maintenance and 32.2 mg. N for growth as in equation (B).
[3] N × 6.25.

It is concluded that the above requirements, which are based on factors for maintenance and growth determined in one laboratory and are in agreement with data reported by others, should closely approximate the actual energy and protein requirements of young dairy calves. The accuracy of these requirements was tested in growth studies to be reported in another publication.

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TUDIES ON THE DESIGN OF COMPARATIVE POULTR Y TEST S

1. A COMPARISON OF THREE STRAINS OF WHITE LEGHORNS HOUSED IN REPLICATED FIFTY-BIRD PENS AND INTERMINGLED IN A LARGE PEN

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ABSTRACT

An experiment was conducted to estimate the magnitude of the pen effects and to compare the performance of three genetically different S.C. White Leghorn strains in twelve small pens (50-bird size) and a large intermingled group (a pen of 677 birds).

There were no significant pen effects for any traits. The repeatability (intra-class correlations) estimates for all traits measured were relatively high: hen-housed egg production, .83; survivor egg production, .77; 160-day body weight, .93; March body weight, .94; laying-house mortality, .47; and feed efficiency, .84.

Although strain differences were highly significant, there was no difference in egg production or mortality between the birds in the small pens and in the large intermingled group, and no evidence of any strain x replicate interaction.

On the basis of this study, it is concluded that there is no advantage to intermingling strains after housing in order to compare their genetic merit, when an adequate number of uniformly equipped small pens are available and the management of the pens is very similar. There are two main disadvantages to intermingling strains, namely, the loss of feed consumption data, and the cost of trapnesting the birds in the test.

INTRODUCTION

The increasing use being made of the "random sample test" as a means of evaluating different strains of poultry has focused attention on the need for securing critical information on the most suitable rearing and housing procedures for these tests. To date there has been little experimental work reported that deals directly with this problem, particularly on the comparison of strains with different genotypes located in separate pens of the same test house.

The present experiment was designed: (a) to estimate the reliability of a 50-bird sample; and (b) to compare the performance of different strains housed individually in 50-bird pens with the performance of the same strains intermingled in one large pen containing over 600 birds.

LITERATURE REVIEW

The need for and theoretical practicability of testing strains at a central location has been demonstrated by Gowe and Wakely (2), who reported that relatively large location effects were common, but interactions between strain and location were not found. King (5, 6), after analysing data from the Cornell Random Sample Tests, showed that the repeatability of some economic traits was of a fairly high order. However, there were no replications in these tests except when years were considered, and several factors were confounded when correlations were made between entries from different years. Repeatability was not as high as would have been expected within years.

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Under such specific stress conditions as severe disease exposure and extreme nutritional deficiencies in the diet, strains and breeds have been shown to respond quite variably, indicating that there are highly significant interactions between strain genotypes and these extreme environments. Literature on this subject has been recently reviewed by Gowe and Wakely (2) and Merritt and Gowe (7).

Gutteridge and O'Neil (3) and later Gowe and Wakely (2) found no evidence of important genotype-environment interactions when different strains of Barred Plymouth Rocks and Single Comb White Leghorns were tested at widely separated locations. Both investigations did, however, show a highly significant difference among locations and among genotypes or strains. More recently, Gowe (1) has reported a highly significant interaction between strains and location when hens of several strains were housed in floor pens and individual laying batteries, but only for the traits, survivor egg production and March body weight. Also, Merritt and Gowe (7), working with ten broiler strains, reported evidence of strain by location interactions for two traits (6-week body weight for males and breast angle for females), but they considered the interactions demonstrated in this experiment were of a low magnitude (less than 2 per cent of the total variance) and thus relatively unimportant.

Jaap (4) reported on the performance of light and heavy breed strains of fowl intermingled in one pen compared with the same strains housed in separate pens during the laying period, and concluded that "individual strain and cross comparisons revealed no distinct detrimental effect from the intermingling method of management when one Leghorn, two 'Leghorn-Heavy' crosses, and five Heavy breeds were intermingled during the laying periods".

MATERIALS AND METHODS

Samples of hatching eggs were secured in 1954 from three unrelated strains of Single Comb White Leghorns, referred to in the text as A, B, and C strains.

Eggs of the three strains were incubated and hatched in one machine at the Poultry Division of the Central Experimental Farm, Ottawa. The trays containing eggs of a single strain were randomized in location throughout the incubator and hatcher.

The chicks were sexed on hatching and wing banded by strain. A total of 1375 female chicks of the three strains were distributed at random into each of the four compartments of the 13 shipping boxes, and shipped by air-express to the Experimental Farm at Kentville, Nova Scotia. The chicks were placed under brooders at Kentville the day following the date of hatch (May 6), and were distributed at random into six brooding pens, with the restriction that an equal number of each strain was put in each pen. Each brooding pen had a floor area of 16′ × 16′ and was equipped with an infra-red heat lamp unit consisting of six 250-watt infra-red heat bulbs. All birds were vaccinated for bronchitis with a spray type live virus vaccine at 52 days of age. No unusual effects were observed from the vaccination.

The same feeding program was used on all birds throughout the test. A chick starter containing sulfaquinoxaline as a coccidiostat was used at

the preventive level of 0.0125 lb. per cwt. This chick starter* had a calculated protein analysis of 20.3 per cent. The chick starter was fed *ad libitum* during the brooding and rearing period. Whole oats and whole wheat were also fed *ad libitum* commencing at 42 and 84 days respectively. All birds had free access to oyster-shell from 42 days of age to the end of the test period. All birds had free access to poultry grit throughout the test period.

At 23 days of age, a mild outbreak of coccidiosis occurred but treatment with sulfamethazine brought it under control. All test birds were moved to a poultry range at 56 days of age and distributed at random into range shelters.

The laying test house was a newly constructed gable-roof, one-storey building, with floor dimensions of 135′ × 40′. This building was situated so that the ends of the building faced east and west. The eastern half of the building contained twelve pens, each with floor dimensions of 10′ × 17′ (the pens were designed to house 50 hens). A centre alleyway, 6′ in width, divided the pens so that there were six pens on the south side of the building and six pens on the north side. These pens were numbered consecutively, the pens on the south side being numbered 1 to 6 and on the north side 7 to 12, inclusive. No. 1 pen was located opposite pen No. 12. The west end of the building consisted of one large pen, with floor dimensions of 60′ × 40′. This large pen was separated from the small pens by a central feed and egg room with floor dimensions of 15′ × 40′. Ventilation of the building was provided by the manual adjustment of windows.

Two 50-bird-size pens for each of the three strains were selected at random for each of the north and south sides of the east end of the laying test house. Therefore, there were four 50-bird size pens for each strain, two on the north and two on the south side of the house.

The birds were housed at 145 days of age, all birds with even-numbered wing-bands being placed in the west pen and the birds with odd-numbered wing-bands placed at random in the respective small pens. At 160 days of age, the small pens were each reduced at random to 50 birds, with the surplus odd-numbered birds placed in the west pen. At the beginning of the laying test period the average floor space was approximately 3.5 sq. ft. per bird. The laying test period commenced at 160 days of age and was completed at 500 days of age. All birds were "specked" with all-plastic mechanical anti-picking devices called "Spectrons" at 160 days of age as a deterrent against cannibalism. Body weights were measured and recorded to the nearest 10 grams at 160 days of age in March and again at 500 days of age. Up to 160 days of age, there were 0.3 eggs laid per bird housed. These eggs were not included in the data to be presented.

All laying pens were lighted continuously with electric lights for 13 hours each day from 160 days to 500 days of age.

During the laying test period, all birds were trapped 7 days per week, although trap records were only recorded for 5 days per week (Mondays to Fridays, inclusive). Records on a 7-day basis were kept on each of the twelve small pens on total pen egg production, mortality and feed consumption. All test birds were fed and managed in as similar a manner as

* Poultry Division, Central Experimental Farm, Ottawa, 1954.

TABLE 1.- EGG PRODUCTION, LAYING HOUSE MORTALITY, BODY WEIGHTS, FEED EFFICIENCY AND GRIT AND OYSTER-SHELL CONSUMPTION OF 3 LEGHORN STRAINS HOUSED IN 50-BIRD SIZED PENS AND IN AN INTERMINGLED GROUP

Strain	Pen	Side of house	Females housed 160 days No.	Mortality 160 to 500 days %	Mean egg production 160 to 500 days			Feed per dozen eggs lb.	Mean body weight			Mean*** oyster-shell consump. lb.	Mean*** grit consump. lb.
					Hen-housed* No.	Survivor* No.	Hen-housed** No.		160 days gm.	March gm.	500 days gm.		
Small pens													
A	4	South	50	6.0	238	249	238	4.65	1629	1956	1977	4.25	1.39
	6	South	50	14.0	239	260	240	4.26	1529	1823	1863	4.21	1.46
	10	North	50	16.0	225	244	226	4.76	1560	1883	1960	4.29	0.95
	12	North	50	14.0	227	252	227	4.45	1576	1914	2036	4.38	0.82
Means			200	12.5	232	252	233	4.53	1574	1895	1959	4.29	1.16
B	2	South	50	8.0	231	239	233	4.90	1769	2170	2271	4.01	1.51
	5	South	50	8.0	241	252	243	4.63	1760	2079	2145	4.11	0.92
	8	North	50	6.0	241	256	243	4.56	1789	2121	2190	4.35	2.05
	9	North	50	4.0	235	245	237	4.92	1766	2085	2140	4.07	1.78
Means			200	6.5	237	248	239	4.75	1771	2114	2186	4.13	1.57
C	1	South	50	12.0	217	234	219	5.20	1680	2229	2248	3.99	1.21
	3	South	50	14.0	214	227	218	5.41	1665	2219	2313	4.76	1.18
	7	North	50	10.0	210	224	213	5.40	1653	2215	2277	3.99	1.36
	11	North	50	10.0	218	232	220	5.34	1643	2236	2335	4.38	2.57
Means			200	11.5	216	230	218	5.34	1660	2225	2293	4.28	1.58
Combined South			300	10.3	230	244	232	4.83	1672	2081	2136	4.21	1.25
Combined North			300	10.0	227	242	228	4.89	1665	2078	2160	4.24	1.60
Combined Total			600	10.2	228	244	230	4.87	1668	2080	2148	4.23	1.44
Intermingled pens													
A			215	10.7	234	256			1548	1830	1941		
B			237	10.5	228	246			1755	2019	2116		
C			225	10.2	216	228			1628	2123	2244		
Combined			677	10.5	225	244	229	4.79	1647	1995	2103	3.49	0.51
Over-all			1277	10.3	227	244	299	4.82	1657	2035	2124	3.84	0.95

* 5-day trap data converted to 7-day.
** 7-day pen record, including floor eggs.
*** Calculated on a hen-day basis.

TABLE 2.—ANALYSIS OF VARIANCE OF EGG PRODUCTION AND OTHER TRAITS OF 3 LEGHORN STRAINS HOUSED IN 50-BIRD SIZED PENS AND IN AN INTERMINGLED GROUP

Source of variation	Hen-housed egg production[1]		Survivor egg production[1]		Hen-housed egg production[2]		Laying house mortality		Body weight 160 days		March body weight		Pounds of feed per dozen eggs produced	
	D.F.	M.S.	D.F.	M.S.	D.F.	M.S.	D.F.	M.S.	D.F.	M.S.	D.F.	M.S.	D.F.	M.S.
Small pens														
Strains	2	13944.00**	2	13203.01**	2	489.25**	2	41.33**	2	19576.43**	2	53203.98**	2	6958.58**
Side of house	1	1008.80	1	182.45	1	52.08	1	0.33	1	78.48	1	16.90	1	120.33
Strains × side of house	2	1417.03	2	595.43	2	56.08	2	21.33	2	183.11	2	119.28	2	76.58
Replicates	6	409.89	6	2284.61					6	473.72	6	1142.27		
Error	588	2471.88	527	1229.86	6	15.91	6	6.33	588	258.06	558	480.97	6	415.33
Over-all														
Strains	2	22201.13**	2	32244.67**					2	44123.91**	2	97304.68**		
End of house	1	861.15	1	37.71					1	1431.16*	1	21354.10**		
Strains × end of house	2	1901.45	2	715.10					2	310.20	2	1265.15		
Error	1271	2526.41	1139	1125.43					1271	255.12	1202	580.20		

1. Analysis calculated on 5-day trap.
2. Analysis calculated on 7-day pen production which includes floor eggs.

* Significant at the 5% level.
** Significant at the 1% level.

possible. All birds were fed an all-mash hatching ration* which had a calculated protein analysis of 15.1 per cent. This all-mash ration had a medium-fine grind and was fed *ad libitum* in hanging circular tube-type feeders which were replenished twice each week. The tubes of these feeders were approximately 9 inches in diameter and 26 inches in height and the feed pans were approximately 16 inches in diameter. These feeders were provided for all birds in the experiment at the rate of six per 100 birds housed. One cup-type waterer was provided for each 50 birds. All birds had free access to oyster-shell and grit throughout the laying test period.

There was no culling at any time throughout the test except at hatching-time when crippled chicks were removed.

RESULTS

Hatchability of fertile eggs for the three strains was *A strain*, 89 per cent; *B strain*, 85 per cent; and *C strain*, 84 per cent. Two per cent of all chicks hatched were crippled and were removed at hatching-time.

Of the 1375 female chicks shipped to the Kentville Farm, only four chicks, or 0.3 per cent, were dead on arrival. Mortality during the brooding and rearing period (0-159 days) in the entire test population was 6.1 per cent, with mortality varying from 5.0 per cent to 6.7 per cent between strains.

Data on egg production, mortality, body weights, feed efficiency, and grit and oyster-shell consumption are presented in Table 1. Egg production figures, based on individual hen 5-day week trap records, are presented on a converted 5 to 7-day basis and an actual 7-day basis for the small pens. The number of females housed was 1277, including 415 housed of A strain, 437 of B strain and 425 of C strain.

Analyses of variance of the egg production and other traits for the birds housed in small pens and the intermingled pen are presented in Table 2. The analyses for hen-housed and survivor egg production were carried out, using 5-day trap records for individual hens. Analyses of variance for egg production records in the small pens, on a 7-day basis, are also presented in Table 2. The results for the twelve 50-bird size pens will be discussed first, followed by the results obtained comparing the performance of the three strains in the replicated small pens with the same three strains in the large intermingled group.

Small Pens

There was a significant difference between strains in both hen-housed and survivor egg production. The close agreement between the north and south sides of the house was remarkable, resulting in no significant difference between sides of the house. The mean hen-housed egg production on the south side of the house was 230 eggs and on the north side the mean egg production was 227 eggs. The mean survivor egg production on the south and north sides of the house was 244 and 242 eggs respectively.

* Poultry Division, Central Experimental Farm, Ottawa, 1954.

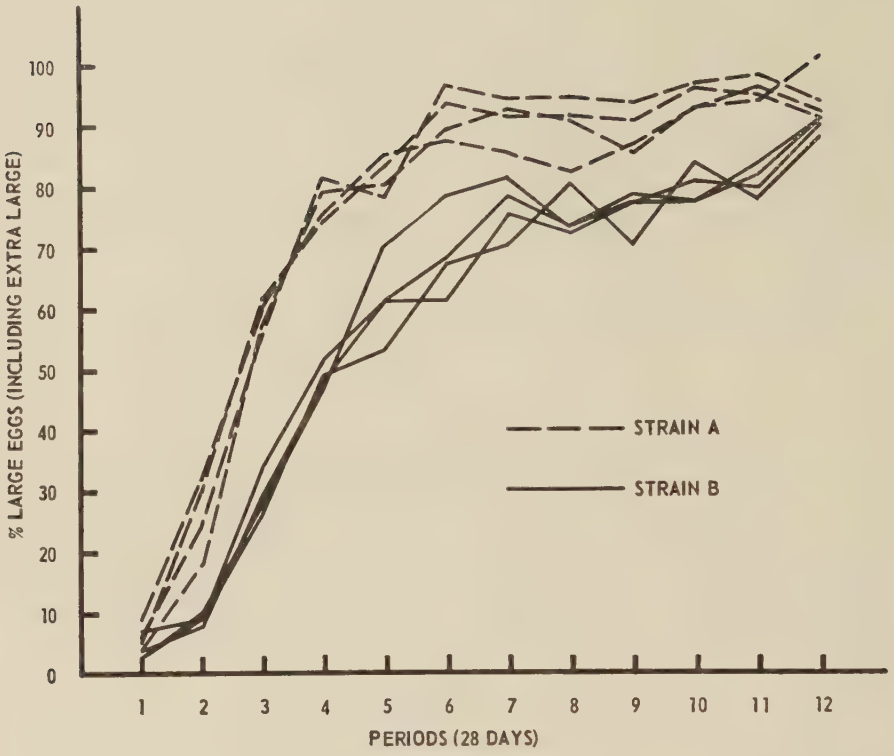

FIGURE 1.

There was no significant difference in egg production within strains among the four pens which housed 50 birds each. Mean hen-housed egg production varied from 225 to 239 eggs in A strain, 231 to 241 eggs in B strain, and 210 to 218 eggs in C strain.

There was no evidence of a strain x pen interaction in hen-housed and survivor egg production.

An analysis of variance of the 7-day production records of the birds in the small pens is presented in Table 2. There was a significant difference between strains but the difference between the north and south sides of the house and between pens was not significant. There was no significant interaction between strains and location.

There was a significant difference between strains for mortality which varied from 6.5 per cent in B strain to 12.5 per cent in A strain. There was no significant difference between sides of the house, with mortality on the south and north sides being 10.3 per cent and 10.0 per cent respectively. Evidence of interaction between strains and side of house for mortality could not be demonstrated.

Although there was a significant difference between strains in feed efficiency, A, B and C strains requiring 4.53, 4.75 and 5.34 lb. of feed per dozen eggs produced respectively, there was no significant difference between sides of the house, with the south and north sides having a feed efficiency of 4.83 and 4.89 lb. of feed per dozen eggs produced respectively.

TABLE 3.—REPEATABILITY ESTIMATES OF VARIOUS TRAITS OF 3 STRAINS OF LEGHORNS HOUSED IN 50-BIRD SIZED PENS.

Traits	Repeatability
Hen-housed egg production*	.83
Hen-housed egg production**	.80
Survivor egg production*	.77
160-day body weight	.93
March body weight	.94
Mortality	.47
Feed efficiency	.84

* Based on 5-day trap.
** Based on 7-day pen production which includes floor eggs.

No significant interaction was found in feed efficiency between strains and side of the house.

There was a highly significant difference between strains for 160-day and March body weights based on data from the small pens. No significant differences were found in either housing body weight or March body weight between sides of the house or between pens, and no evidence of a strain x pen interaction was demonstrated for this trait.

From October 31 to September 17, with the exception of February, March and April, all eggs laid on Mondays, except broken eggs, were graded for size according to Canadian standards and these grades were applied to the total weekly egg production less broken eggs. During the months of February, March and April, the same procedure was followed, except that egg gradings were made every 2 weeks and these grades were applied to the total 2-week egg production less broken eggs.

The per cent Large and Extra Large eggs produced between November 7 and September 10 was plotted by pens and presented in Figure 1. This figure shows there was a close agreement between pens within strains. A similar close agreement between replicates of strain C was observed but the data for strain C were not used in order to avoid confusing the figure.

To estimate the repeatability of various traits for the different pens of the same strain, intra-class correlations were calculated. These are presented in Table 3. The repeatability estimate of hen-housed egg production was slightly higher than survivor egg production, probably due to the rather close agreement between replicates for laying house mortality. These estimates were all of a high order as were those for 160-day and March body weights and for feed efficiency.

Comparing the intermingled pen and the small pens on a combined basis, that is, the large intermingled pen compared with the whole of the twelve small pens, there was no significant difference for mortality, egg production (hen-housed and survivor) and feed consumed per dozen eggs produced (Table 2). There was, however, a difference in 160-day and March body weights. The difference in 160-day weights was significant at the 5 per cent level and the difference in March body weights was significant at the 1 per cent level. The mean March body weight in the intermingled pen was 1995 grams compared with a mean body weight of 2080 grams in the twelve small pens. The difference in body weight decreased toward

the end of the test period, so that the mean 500-day body weights in the small pens and intermingled pen, (Table 1), were 2148 and 2103 grams respectively.

Oyster-shell and grit consumption data are included in Table 1. These data were not subjected to statistical analysis and are not considered of particular importance, except to show the considerable variability in grit and oyster-shell use. Observations would strongly indicate this was due for the most part to improperly designed feeders that permitted excessive wastage in some pens.

DISCUSSION

The important observation in this experiment is the remarkably close agreement for all traits measured among small pen replicates within strains as well as the close agreement between the intermingled group and the twelve small pens, with the one exception of body weight.

It would appear that the intermingling of strains in one pen in this case placed some greater stress on the birds which resulted in reduced body weight. Data just available from a repeat experiment show that body weight differences between the small pens and the intermingled group were not repeated. It was observed that the birds in the intermingled group in the repeat experiment were much less flighty than was the case in the previous experiment reported here. Care was taken in the second test to see that the birds in the large pens "settled down" as quickly as those in the small pens and this body weight difference was not encountered. Apparently body weight is a more sensitive measurement of minor environmental factors than egg production, since differences in egg production were small and insignificant. Since body weight is an easily measured trait, it should perhaps be measured, reported and studied more frequently as an indication of environmental conditions in an experiment or test.

In general, our results substantiate Jaap's (4) observations that intermingling of strains had no apparent detrimental effect. If the pens available for comparing strains differ greatly in size, shape or construction so that pen effects could play a part in comparing strains, it would seem to be preferable to intermingle the strains being compared.

The relatively low level of mortality in this experiment indicates that disease exposure was at a low level, at least for the diseases which do not respond to preventive medication or vaccination. The measurement of strain resistance to diseases which have no immediate practical control other than by breeding for resistance to the disease would be highly desirable, particularly for diseases such as leucosis which are widespread in the industry. The random sample tests conducted at Cornell University by King (5, 6) have been measuring strain resistance to this disease by a natural exposure program with considerable success. For diseases such as leucosis it is suggested that exposure would be approximately equal if the strains were intermingling during the brooding and rearing period. After the strains are separated pen effects could be important under conditions where there was a severe disease exposure in some of the test pens and not others. A genotype x pen-location interaction could possibly be demonstrated under such conditions, but these are not likely to be encountered,

and if such conditions become evident they could be noted and the comparisons repeated another year.

Other than providing a theoretically more uniform environment, the intermingling of strains in the laying house does not appear to offer any particular advantage over housing strains in individual pens after rearing the strains intermingled. It is suggested that the degree of importance placed on this theoretically more uniform environment for the strains being compared depends on the physical nature of the facilities available. If identical pens are available and if the management of the test is prepared to exercise great care in the operation of these separate pens to see that conditions are kept uniform, it is probably better to house the strains in separate pens so that feed consumption and complete 7-day egg production records can be obtained for the different strains. Also, it is possible to reduce labour costs by eliminating trapping when individual pens are used to house each strain. If there are significant differences between strains in temperament, it may be important to house them separately to prevent a real bias developing. There was no evidence of such a difference existing between the three strains used for this experiment.

Direct comparisons between the repeatability estimates obtained by King (5, 6) with those obtained in this experiment could be misleading. As has been pointed out, many factors are included in the replicates over three years for the Cornell tests for a single strain, not the least of which may be the improvement and changes in stock the breeder may have made in his breeding program. Despite this limitation, it may be advantageous to make some comparisons. The repeatability estimates for laying house mortality for the two reports published by King were .72 and .63. In the present experiment, the estimate was only .47. For other comparable traits, such as hen-housed egg production, King reported .41 and .29 for within breed estimates. An estimate of twice that value was obtained in this test of .80.

Although it is impossible to draw any positive conclusions, it would appear that the repeatability estimate for livability should be higher where the leucosis exposure levels are higher, as they are in the Cornell tests. A controversial point is whether a test which is intended to demonstrate the comparative genetic worth of stock, supposedly under farm conditions, should be designed to reveal more accurately the inherited resistance to disease or the inherited ability to lay eggs. Obviously the egg producer who has a continuous problem with leucosis on his plant would want one kind of test, while the egg producer who has a relatively low exposure to the disease may prefer a test that does not emphasize disease resistance.

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OBSERVATIONS ON GENOTYPE-ENVIRONMENT INTERACTION IN SWINE[1]

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ABSTRACT

An experiment was carried out to evaluate the importance of genotype-environment interactions in Canadian Yorkshire swine. Two males and two females from each of four litters by each of four sires were randomly allotted to two feeding and management treatments. One male and one female from each litter were self-fed A.R. feed mixtures in a piggery and the other male and female were self-fed the same feeds on pasture. Weights were taken at 56 and 140 days of age and at 190-200 lb. live weight. Carcass measurements were taken at slaughter.

Rate of gain from 56 to 140 days for pasture-fed pigs was significantly lower ($P = <.01$) than for those fed in the piggery. Pigs fed on pasture were also significantly shorter ($P = <.01$) than those fed in the piggery. Sire-treatment interaction was significant for loin area ($P = <.05$) and approached significance for rate of gain from 56 to 140 days ($P(=).09$), A.R. carcass score ($P(=).13$), and average backfat thickness ($P(=).08$). A marked shift in ranking of sires between treatments was noted for loin area, rate of gain, and A.R. carcass score. These results indicate that genotype-environment interactions may exist in Yorkshire swine.

INTRODUCTION

When the relative desirability of genotypes within a series shifts with a change in environment a genotype-environment interaction exists. The presence of such a phenomenon among livestock would have several serious implications from the viewpoint of livestock improvement. If such an interaction existed between genotypes and the environments in certain definable areas, the development of specialized strains for each area would be indicated. On the other hand, if an interaction existed between genotype and season or year within a given herd or flock, the effectiveness of selection for the trait in question could be affected.

Genotype-environment interactions are well known in plant breeding and are reported in almost every publication on variety trials. However, information on such interactions in large animals is scarce. Bonnier *et al.* (1), in a study of monozygous cattle twins, report non-linear interactions between heredity and environment for growth, milk yield, and butterfat percentage. King and Young (4), in a study of three breeds of sheep wintered in four environments, detected breed-environment interactions for certain skeletal growth measurements. Young (6), in a study of mice reared under four different temperature and feeding conditions, found evidence of genotype-environment interaction for growth and certain reproduction traits. Haldane (3) has discussed the subject of genotype-environment interaction and has pointed out that there are several types of interaction which can occur.

Falconer (2) has suggested that when a single trait exhibits a genotype-environment interaction under two environments, it should be considered as two separate traits. When the genetic correlation between them is

[1] Contribution from the Division of Animal Husbandry, Experimental Farms Service.

calculated the consequences of selecting for one trait under one environment upon the response for that trait under the second environment can be estimated.

The consequence of large genotype-environment interactions may be particularly important under a breeding program such as the Canadian National Bacon Hog Policy where litter samples are tested under a special test-station environment. In practice the assumption is made that selection for performance under the test-station environment is equivalent to selection for the same traits under all commercial environments in common use in Canada. If genotype-environment interactions are important heavy selection pressure for performance under test-station conditions could result in only minor improvement in performance under some commercial environments and possibly in a reduction in performance under other commercial environments.

This report describes the results of the first of a series of investigations into the subject of genotype-environment interaction in Canadian Yorkshire swine.

PROCEDURE

Four litters from each of four different sires, and containing a minimum of two males and two females, were selected for this trial. Due to the range in birth date, the first-born litters by each of the sires were designated as *replicate 1*, the second-born litters as *replicate 2*, etc., providing four replicates. From each litter two males and two females were selected at random and one male and one female were randomly allocated to each of two feeding and management treatments. Each male-female pair from the same litter allocated to the same treatment was penned separately, making 16 pens on each treatment. One male and one female from each litter were self-fed in a conventional piggery and the other male and female were self-fed on an alfalfa-clover-bromegrass pasture. The pelleted feed mixture fed was identical to that used in the Advanced Registry testing of swine under the Canadian National Bacon Hog Policy (5). All pigs had access to water at all times. The pigs were farrowed in May and placed on test from June 25 to July 25 as they reached 56 days of age, and were fed to a live weight of 190-200 lb., at which weight they were slaughtered and the routine A.R. carcass measurements taken.

Each pig on this trial was weighed at 56 and 140 days of age and at a final weight of from 190 to 200 lb. Growth rate was measured by calculating the average daily gain from 56 to 140 days of age. The carcass traits considered in this trial were Advanced Registry carcass score, length of carcass from the aitch bone to the first rib, area of the loin muscle (longissimus dorsi) at the last rib, and the average of the three backfat measurements taken at the shoulder, mid-back, and loin (5). Where a gain in precision of the experiment could be made through adjusting data by covariance techniques for uncontrolled effects this was done.

RESULTS

The pigs on this trial reached market weight at from 146 to 200 days of age which is within the range experienced for normal pigs at this experimental farm.

The test of significance for the interaction effects applied in the analysis are the standard F tests and do not specifically test the significance of any shifts in ranking of sires between treatments. A significant interaction under these tests merely indicates that the effect of a sire is not always the same but depends upon the treatment under which the sire's progeny were tested. Since the shifts in ranking of sires between treatments are of interest the rankings of the sires under each treatment are presented in the tables which follow.

Rate of Gain from 56 to 140 Days of Age, Adjusted for 56-Day Weight

Preliminary analysis indicated that a significant reduction in the error mean square could be achieved by adjusting the rate of gain from 56 to 140 days of age for differences in 56-day weight. Table 1 presents the most pertinent means for rate of gain from 56 to 140 days adjusted for 56-day weight as well as the ranking of the four sires under each set of test conditions. The four sires involved are identified as S_1, S_2, S_3, and S_4.

The pigs fed out in the piggery gained significantly ($P = <.01$) faster to 140 days of age than did those on pasture. The differences between sires and between sexes were not significant. Sire-treatment interaction approached significance, the F value corresponding to P (=) .09.

A.R. Carcass Score

The analysis of carcass score data indicated a significant difference ($P = <.05$) between sexes. The sire-treatment interaction yielded an F value corresponding to a probability of 0.13. Sire and treatmen effects were not significant. A summary of the data on carcass score is presented in Table 2.

The shift in ranking of sires between treatments was very marked in this trait.

TABLE 1.—RATE OF GAIN FROM 56 TO 140 DAYS OF AGE ADJUSTED FOR 56-DAY WEIGHT (LB. PER DAY)

	Sire 1	Sire 2	Sire 3	Sire 4	Treatment means	Ranking of sires			
						1st	2nd	3rd	4th
Piggery	1.35	1.53	1.35	1.33	1.39	S2	S1	S3	S4
Pasture	1.25	1.31	1.31	1.26	1.28	S3	S2	S4	S1
Sire means	1.30	1.42	1.33	1.30		S2	S3	S1	S4

TABLE 2.—ADVANCED REGISTRY CARCASS SCORE

	Sire 1	Sire 2	Sire 3	Sire 4	Treatment means	Ranking of sires			
						1st	2nd	3rd	4th
Piggery	70.2	69.7	71.5	65.1	69.2	S3	S1	S2	S4
Pasture	58.5	66.4	68.7	73.0	66.7	S4	S3	S2	S1
Sire means	64.4	68.1	70.1	69.1		S3	S4	S2	S1

Length of Carcass

It was found that no significant gain in precision could be made by adjusting length measurements for differences in hot carcass weights. Sire differences were significant at the P = .05 level and treatment differences significant at the P = .01 level. As will be noted from Table 3, pigs raised on pasture were shorter than their littermates raised in the piggery. The difference between sexes was not significant nor was the sire-treatment interaction.

Loin Area

Loin area data were adjusted for differences in hot carcass weight by means of covariance analysis. Table 4 presents the mean loin area for sires, treatments, and sire-treatment subgroups adjusted for hot carcass weight.

Differences between sexes and the sire-treatment interaction were both significant at the P = .05 level. Sire and treatment effects were not significant although the treatment effect approached significance.

Average Backfat Thickness

A significant reduction in error sum of squares was obtained through adjustment of the average backfat measurements for differences in hot carcass weights. The average values for backfat thickness adjusted for hot carcass weight are reported in Table 5.

Differences between sires and sexes were significant at the P = .05 level and the sire-treatment interaction effect approached significance (P(=).08). The means reported in Table 5 for the sire-treatment subgroups indicate that the magnitude of the interaction effect is primarily due to much larger differences between sires on pasture than in the piggery, and not due to any shift in ranking of the sires under the two treatments.

Table 3.—Average length of carcass (in.)

	Sire 1	Sire 2	Sire 3	Sire 4	Treatment means	Ranking of sires			
						1st	2nd	3rd	4th
Piggery	30.0	30.4	30.5	30.1	30.3	S3	S2	S4	S1
Pasture	29.4	29.6	30.1	30.2	29.8	S4	S3	S2	S1
Sire means	29.7	30.0	30.3	30.2		S3	S4	S2	S1

Table 4.—Mean loin area (sq. in.), adjusted for hot carcass weight

	Sire 1	Sire 2	Sire 3	Sire 4	Treatment means	Ranking of sires			
						1st	2nd	3rd	4th
Piggery	3.86	3.56	3.54	3.47	3.61	S1	S2	S3	S4
Pasture	3.64	3.85	3.56	3.74	3.69	S2	S4	S1	S3
Sire means	3.74	3.71	3.55	3.61		S1	S2	S4	S3

TABLE 5.—MEAN BACKFAT THICKNESS (IN.), ADJUSTED FOR HOT CARCASS WEIGHT

	Sire 1	Sire 2	Sire 3	Sire 4	Treatment means	Ranking of sires			
						1st	2nd	3rd	4th
Piggery	1.34	1.29	1.33	1.33	1.32	S2	(S3	S4)	S1
Pasture	1.42	1.22	1.25	1.32	1.30	S2	S3	S4	S1
Sire means	1.38	1.26	1.28	1.32		S2	S3	S4	S1

TABLE 6.—ANALYSIS OF VARIANCE FOR RATE OF GAIN, CARCASS SCORE, LENGTH, LOIN AREA, AND AVERAGE BACKFAT THICKNESS (MEAN SQUARES ONLY)

Source of variation	Degrees of freedom	Rate of gain 56–140 days adjusted for 56-day weight	A.R. carcass score	Carcass length	Loin area adjusted for hot carcass weight	Av. backfat thickness, adjusted for hot carcass weight
Replicates	3	.0193	179.2	.8396	.1825	.0287*
Sires	3	.0591	100.0	1.0929*	.1307	.0421*
Sexes	1	.0395	976.5*	.0506	4.6410*	.0577*
Treatments	1	.2401**	99.9	2.7225**	.1620	.0074
Sires × Sexes	3	.0664	25.6	.2386	.0833	.0148
Sires × Treatments	3	.0660 (P(=).09)	258.7 (P(=).13)	.3921	.2516*	.0213 (P(=).08)
Sexes × Treatments	1	.1170	4.0	.0752	.0001	.0041
Error	33	.0295[1]	134.2	.3260	.0716[1]	.6092[1]

* P =<.05
** P -<.01
[1] Degrees of freedom =32

The type of genotype-environment interaction which involves a shift in ranking of genotypes between environments is of the most general interest, but if the type of interaction observed for backfat thickness in this study is important, the environments which maximize differences between genotypes would be most suitable for testing purposes. There was no significant difference in average backfat thickness between pigs raised under the two environments.

The mean squares for the sources of variation which are of most interest are presented in Table 6. The error term is made up of the second and third order interactions. The approximate probabilities for the F values for the sire-treatment interactions which approached significance have been calculated to indicate the magnitude of the interaction effects relative to the experimental error.

DISCUSSION

The results of this trial indicate that pigs self-fed on pasture tend to gain at a slower rate and have somewhat shorter carcasses than pigs self-fed the same feed mixture in a piggery. There is also a suggestion that pigs self-fed on pasture may have a somewhat larger loin area than pigs self-fed in a piggery.

There was a marked shift in ranking of sires for certain traits under the two management regimes. This trial was based on four litters per sire and two test pigs per treatment from each litter and was, therefore, subject to sizable experimental errors but, on the other hand, the shift in ranking in some cases was very striking. The sire-treatment interaction was significant for area of loin and approached significance for average backfat thickness and for rate of gain from 56 to 140 days of age. The ranking shift for boars 1 and 4 was particularly striking for area of loin. When A.R. score was considered, the major shifts in ranking took place between boars 1 and 4.

The limited size and scope of this experiment precludes the possibility of making any sweeping generalizations concerning the general importance of genotype-environment interactions in Canadian Yorkshires but the results suggest that there is a reasonable doubt concerning the validity of the common working assumption that genotype-environment interactions do not exist in swine. Further trials of increased size and scope on this problem are now in operation.

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NOTE ON A CHROMIUM OXIDE PELLET TO PROVIDE UNIFORM RELEASE OF THIS INDICATOR IN THE RUMEN OF CATTLE[1]

Chromium oxide (Cr_2O_3) has been studied intensively as an external indicator for estimating fecal dry matter output of grazing ruminants. One of its chief limitations is associated with its uneven excretion when administered in gelatin capsules once or twice daily. This results in a diurnal excretion cycle which may introduce serious errors into dry matter excretion estimates based on analysis of a limited number of fecal samples.

Since the diurnal cycle is primarily a reflection of sudden large doses of Cr_2O_3 entering the alimentary tract, uniform release of Cr_2O_3 over the entire 24-hour period should promote its more uniform excretion.

A "sustained-release pellet" (S.R.P.) has been developed to dispense Cr_2O_3 in the rumen. The pellet is composed of Cr_2O_3, 25 parts, Kerr's Plaster No. 2[2], 25 parts, and water 31 parts (by weight) moulded into a cylinder 7/8 in. diameter and 2½ in. long; this dissolves in the rumen during a period of approximately 96 hours. Pellets are administered once daily by balling gun. Although decrease in volume of an individual pellet results in progressively less Cr_2O_3 being released, the length of time required for each pellet to dissolve results in an overlapping effect (i.e., 3 or 4 capsules are in the rumen at all times), so that relatively uniform release of Cr_2O_3 is obtained.

No evidence of regurgitation or of passage of pellets out of the rumen and through the digestive system before they have disoslved has been obtained in two laboratory trials and one field trial with cattle. These pellets are not recommended for sheep because regurgitation has occurred in laboratory trials.

The diurnal excretion cycle of Cr_2O_3 has been studied by administering pellets to two cows in the laboratory and to two cows in a field trial. Maximum deviation from relative 9-day average concentration was: laboratory animal No. 1, 94-104 per cent, No. 2, 90-110 per cent; field animal No. 1, 80-117 per cent, No. 2, 93-108 per cent.

This type of pellet should be useful in ruminant nutrition studies for sustained release of antibiotics, trace minerals, etc. Although the rumen life of the 50:50 Cr_2O_3: plaster mixture used in these tests is approximately 96 hours, an increase in the plaster to Cr_2O_3 ratio produces a more durable pellet.

Further details of manufacture of the pellets and testing with animals will be published later.

—W. J. Pigden,
—Germain J. Brisson,
Canada Department of Agriculture,
Ottawa, Ontario.

November 4, 1957.

[1] Joint Contribution from Animal Husbandry Division, Experimental Farms Service, and Chemistry Division, Science Service, Canada Department of Agriculture, Ottawa, Ont.
[2] A commercial dental impression plaster predominantly $CaSO_4{:}\frac{1}{2}\ H_2O$ (Plaster of Paris).

STATEMENT OF EDITORIAL POLICY AND PRACTICE
for the
CANADIAN JOURNALS OF "ANIMAL", "PLANT", and "SOIL SCIENCE"

Types of Manuscripts Accepted

The Agricultural Institute of Canada publishes, in the "*Canadian Journal of Animal Science*", the "*Canadian Journal of Plant Science*", and the "*Canadian Journal of Soil Science*", papers reporting original research on matters relating directly to technical agriculture. Reviews of a general or purely informative nature are not usually accepted, although the Editorial Board reserves the right to invite or accept authoritative reviews from time to time.

The Editors are prepared to accept a limited number of Notes as follows:

(a) *Research Notes*, of such import as to warrant immediate release. It is expected that such Notes will be followed up by more detailed presentations or that results will be included in some subsequent, more extensive publications.

(b) *Technical Notes*, dealing with subjects such as laboratory techniques, field observations and special equipment. Such Notes would be of assistance to the research worker but would not warrant full-length publication. They would not receive the same priority of publication as would research notes.

Papers submitted must not have been published elsewhere or copyrighted. They should be as concise as is compatible with clarity. Literature reviews should be limited to only the most pertinent references. The nature of the study should be clearly stated and its scope should be defined. Results should be presented as tables, or as figures, or in the text. Presentation in more than one of these ways is definitely undesirable.

Editorial Board

The three Journals have a common Editorial Board, appointed by the National Council of the Agricultural Institute of Canada, and consisting of (a) eight members, each of whom serves for a 4-year term and two of whom retire each year; and (b) two other members, the Executive Secretary, ex officio, and a representative of the Canada Department of Agriculture. The members are selected so as to represent all fields of agriculture. The Board is responsible for making recommendations to National Council concerning editorial policy and practice for the three scientific Journals.

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Agronomy, the Canadian Phytopathological Society, and the Canadian Society for Horticultural Science. For the "*Canadian Journal of Soil Science*", there are two representatives of the Canadian Society of Soil Science; and for the "*Canadian Journal of Animal Science*", there are two representatives of the Canadian Society of Animal Production.

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The members of the Editorial Board and the Society representatives are responsible for (1) seeing that the manuscripts submitted for publication are properly reviewed; (2) preparing the necessary editorial comments; (3) accepting or rejecting the final submissions, bearing in mind the high standards desired. The present policy of the Board envisages the ultimate establishment of research journals which will have international recognition in their fields. To accomplish this, the standards, not only for quality of work but also for its presentation, must be high.

The Editor receives the manuscript and, in consultation with the Managing Editor, decides on the Editorial Board member or Society representative who is most likely to have some acquaintance with the subject matter of the paper, to whom the paper is then submitted. On its receipt, the person selected will normally have the paper reviewed by two other workers, independently. In those cases, however, where he feels that the subject is within his own area of competence, a review by one other worker may be sufficient. He will use the reviews, together with his own estimate of the paper, to prepare the final editorial comments which will be returned to the Editor for transmission to the author.

The reviewer is directed to assess the extent to which the paper submitted does in fact represent a piece of research carried to a well-defined stage of advance and the extent to which the conclusions are adequately supported by the experimental results. He should aim at inducing the author to condense and systematize his paper whenever necessary and to use judgement in selecting critical or representative results for presentation. He should scrutinize the paper carefully to ensure that the conclusions are sound and that the facts established by the actual investigation are not advanced in support of conclusions other than those which are legitimate. He should encourage authors to keep matters of speculation and expressions of opinion at a minimum, and to present them in short, clear statements. Every reasonable effort should be made to excise redundant, ambiguous or imprecise words, phrases or passages.

Editorial Comments

The aim of the editorial comments is to assist the author and to secure his co-operation in producing a better paper. In their preparation, the Board member or Society representative is responsible for answering the following questions:

(a) *Does this paper contain sufficient original material to justify publication in a journal devoted to original work?*

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1. *inappropriate for the journal and therefore unacceptable?*
2. *acceptable as it stands?*
3. *acceptable subject to minor revision?*
4. *acceptable subject to major revision?*
5. *unacceptable?*

In those cases where the author believes that the editorial comments are not well founded, he has the privilege of asking for another independent review.